POST-WAR BUILDING STUDIES
NO. 19

HEATING AND VENTILATION
OF DWELLINGS

BY THE HEATING AND VENTILATION
(RECONSTRUCTION) COMMITTEE
OF THE BUILDING RESEARCH BOARD
OF THE DEPARTMENT OF
SCIENTIFIC & INDUSTRIAL RESEARCH

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POST-WAR BUILDING STUDIES

The series of Reports being published under the title of Post-War Building Studies owes its origin to a desire expressed by professional and other institutions connected with the building and civil engineering industries to assist and support the Ministry of Works in regard to post-war plans. During the latter part of 1941 the then Minister, in order to take advantage of these offers of assistance which he was receiving from all quarters, encouraged the establishment of a series of Committees to investigate and report on the major problems which were likely to affect peace-time building. He also offered, on behalf of the Ministry, to provide the necessary staff and organization to co-ordinate the various inquiries, in such a way as to avoid duplication of effort and to secure so far as possible uniform direction and policy.

A list of the Reports in this Series is given on the back page of the cover.

The Committees were either appointed by a Government Department or convened by a professional institution, a research association or a trade federation, as seemed most appropriate in each case; they were so constituted as to ensure that the Reports contain the considered views of experts and others closely concerned with the subject. The Minister gratefully acknowledges the work of the Committees and the valuable assistance given both by the various convening bodies and by the individual members. The Reports are not official publications in the sense that the Government as such is responsible for or necessarily accepts the views expressed, but their contents are authoritative and must be of great value to all now concerned with preparations for building.

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DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

THE HEATING AND VENTILATION (RECONSTRUCTION) COMMITTEE OF THE BUILDING RESEARCH BOARD

G3—

To the Building Research Board.

GENTLEMEN, We, the Heating and Ventilation (Reconstruction) Committee, beg leave to present a Report on the Heating and Ventilation of Dwellings, giving the results of the consideration which we have given to the subject following our appointment in July 1942, with the following terms of reference:

i. To review existing scientific information and practice in this country and abroad on the heating and ventilation of buildings.

ii. To make recommendations for practice in post-war building, regard being had both to economy and efficiency for the individual user and to the economical utilization of the national fuel resources.

iii. To make such recommendations for further research as may suggest themselves in considering (i) and (ii).

We have had six meetings in full Committee, taking as our first task the problem of the heating and ventilation of dwellings, in accordance with the order of priority which was suggested to us. At our first meeting, we received, as a basis for the consideration of the heating of dwellings, a statement of information assembled by a Departmental Group comprising members of the staffs of the Building Research Station and Fuel Research Station, together with Sir Alfred Egerton (Chairman), Mr. J. H. Markham, Mr. W. W. Nobbs, and Mr. A. C. Pallot. This Group had for some time been conducting inquiries into the subject, and it has continued to meet during the course of our deliberations, giving us much assistance. The Group suffered a great loss by the death in January 1943 of Dr. F. S. Sinnatt, Director of Fuel Research, who had taken a very great interest in the work.

In the first instance, we arranged for the statement to be considered separately by sections of the Committee, each consisting of members having specialized experience in particular directions—for example, on heating by solid fuel, by gas, or by electricity, or in the general field of heating and ventilating engineering. Subsequent to this first examination of the statement, those members specially conversant with the problems of heating by each of the different fuels, together with some other members of the Committee, have collaborated in a more detailed consideration of the subject, and for this purpose they have held a number of informal meetings. They wish to place on record the great value of the exchange of views which took place at these meetings and of the mutual co-operation thus established.

The subject of domestic heating (including water heating and cooking) is a complex one, for among the many factors which have to be taken into account in reaching a decision on the type of heating to be employed are the very different requirements and preferences of different families, the variety of appliances or combinations of appliances which are available, and the relative costs of the different fuels in various localities. All these factors intimately affect the householder. From the standpoint of the nation as a whole, as distinct from that of the individual, certain considerations affecting the wisest use of our national coal resources have also to be taken into account.

There is thus no single answer to the question "What is the best system of heating for domestic purposes?" Even taking things as they stand to-day, a great deal depends on circumstances; and looking towards the future, the trend of practice must inevitably be influenced by developments in the fuel industries themselves, the nature of which cannot be predicted, so that the arrangements made must be sufficiently flexible in order to take advantage of these developments. We have taken the view, therefore, that the best service which we could render was to set down a basis on which decisions in particular cases could be arrived at, by discussing the various factors which need to be taken into account, rather than to suggest what the decisions should be. With that in mind, we have proceeded, after a general introduction (Chapter 1), firstly to set out the average conditions of warmth and ventilation which are desirable, and the minimum provision for hot-water supply and cooking (Chapter 2); secondly to find the amount of heat theoretically needed in an average house to provide these basic facilities and how this amount is affected by the construction of the house, the layout of the hot water system, etc. (Chapters 3 and 4); and thirdly to discuss the various factors relating to the choice of methods of heating (Chapters 5-7). The ventilation of dwellings is dealt with in Chapter 8, and the special conditions of rural housing are also discussed (Chapter 10). Certain other matters incidental to the main theme, including clothes washing (Chapter 9), foreign practice (Chapter 11), development in appliances, and their installation and use (Chapter 12), the testing of appliances (Chapter 13), and the use and distribution of fuel (Chapter 14), are also considered. The report of the Inquiry into the Heating of Dwellings, undertaken by the Wartime Social Survey, forms Appendix 1. A number of other appendices, supplementing or amplifying information in the body of the Report, have also been included: one of them briefly surveys the subject of atmospheric pollution in relation to domestic heating.

Although we have decided unanimously to submit the present Report, it should be explained that every opinion expressed is not necessarily that of every individual member. For example, the standards of heating set out in the Report are considerably higher than were customary in the past, and some of us feel that they represent more than what most people would be able or willing to pay for, and that they would lead to needless consumption of coal, our resources of which have to be conserved. Attention is particularly drawn to the qualifications in paragraphs 2.1.9, 2.3.1, 3.1.2, 3.1.3.1, 6.2.3, 7.2.2.4, and 7.2.4 in the Report.

As has been stated, we considered first the heating and ventilation of dwellings, as it is this branch of the subject which most needs attention, for the heating and ventilation of large buildings is usually entrusted to heating engineers, and the examination of the merits of different schemes for different circumstances is on a well-established basis. But while the Report is primarily directed to domestic premises, some parts of it are of more general application. Statements on the heating of schools and on the heating of buildings other than houses and schools have been prepared by the Department Group already mentioned, but we have not yet completed our consideration of them, so that our Report on these subjects will follow separately.

In view of the developments abroad on district heating, we have thought it desirable to arrange for an examination of the technical merits of the case for the wider adoption of such district heating schemes in this country. At our second meeting a special Sub-Committee was appointed with the following terms of reference:

> "To inquire and report on the desirability of developing in this country schemes for the supply of heat for various purposes by means of steam or hot water from central sources."

The Sub-Committee is making a thorough examination of the subject, and its report is not yet available.

We suffered a great loss by the death of Mr. Stephen Lacey, whose work for the Committee had been invaluable. We were sorry too, when Sir David Milne-Watson found it necessary to resign owing to pressure of other work.

We should also like to acknowledge the valuable assistance given by Mr. C. C. Handisyde in his capacity as Secretary from the inception of the Committee until October 1943, and by Mr. N. S. Billington who then undertook these onerous duties.

We should like to emphasize that we were appointed in our personal capacities, and the Report does not purport therefore to express the views of any of the organizations with which individual members may be connected.

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HEATING AND VENTILATION

A REPORT BY A COMMITTEE APPOINTED BY
THE BUILDING RESEARCH BOARD OF
THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

CHAPTER I. DOMESTIC HEATING

1. 1. DOMESTIC HEATING AND THE INDIVIDUAL

COST OF HEATING

1. 1. 1. The subject of the heating[1] and ventilation of buildings is a complex one. The cost of heating to the householder or factory depends on a train of processes, starting from the winning of the coal in the mine, and ending with its distribution as raw coal, or after conversion into gas, coke, or electricity, to the homes and buildings of this country. The efficiency of fuel production and distribution is reflected in the bill of cost. The costs of heating also depend on the efficiency of the fuel-burning appliances used, and on the construction of the house or other building; a building which is well designed and well insulated against heat loss costs less to keep warm than one which is badly designed. The cost may well turn, furthermore, on the wise choice of the form of heating in relation to the individual requirements: a method of heating which is economical for intermittent use may be expensive for continuous heating.

The factor which most immediately affects the individual is his fuel bill. Partly as a result of generations of cheap and abundant coal, the ordinary person has seldom adopted a critical attitude towards the appliances he uses and the buildings he lives in. The situation has now changed, however, as there has recently been a substantial rise in the price of raw coal, gas, and coke, so that there is ample incentive to the adoption of more efficient and economical methods of heating.

The prices of fuels varied greatly before the war from locality to locality. Generalizations about them are complicated by the types of tariff operating for gas and electricity, which often meant that the average price to the user (per therm or per unit) became less as more use was made of the services. Other factors, such as wages and methods of production in the fuel industries, remain fluid, and will affect the prices at which the various fuels will become available for domestic purposes. Only when definite prices are known will it be possible in each locality to make a satisfactory estimate of the cost of various methods of heating.

HIRE OF APPLIANCES

1. 1. 2. Originally the provision of heating and cooking appliances was a matter for the landlord, and their cost affected the weekly rent. The hire arrangements now in vogue have resulted to a large extent in the occupiers transferring the burden of providing appliances from the landlord's shoulders to their own, and the implications of the change need to be worked out. There appears to be a considerable diversity of hire charges for similar appliances in different localities. Not only this, but in those cases where the landlord had provided unsuitable appliances, the tenant has often purchased or hired others, thus adding to the burden.

[1] Throughout this Report it has been necessary to use the word "heating" to connote, where the text demands, not only room warming (also referred to as space heating), but also water heating, cooking, and auxiliary services such as clothes washing.

AMENITIES

1. 1. 3. All the above factors can be expressed, with greater or less accuracy, in terms of money when prices are known. But there are others which are no less important, upon which no such direct value can be put, such as general convenience and amenity. There is no doubt, for instance, that the electric fire or the gas fire is far more convenient than an open coal fire used intermittently.

THE HEATING OF DWELLINGS INQUIRY

1. 1. 4. Partly in order to shed light on the individual factors affecting the use of fuel in the house, and partly to provide a background of present-day experience against which to work, an inquiry into the heating of dwellings was undertaken (at the instigation of the Departmental Group referred to in the Preamble) by the Wartime Social Survey. The results of the survey form Appendix 1 to this Report. The information asked for was not confined to questions of fact, and people were asked for their opinions on many aspects of the heating of houses. As explained in the introduction to Appendix 1, some of the factors involved were objective, such as household income, family size, expenditure on fuel, methods of cooking, water heating, and room warming, and present habits as to laundry and the purchase of coal. Other important factors covered by the Inquiry were subjective, such as the likes and dislikes about certain types of appliances: these also have to be taken into account in planning any future developments in the domestic heating field. The Inquiry brought out many interesting facts: examples are the greater expenditure on the heating of flats and the larger number of rooms which are warmed in flats, the length of time for which the various rooms are heated, a big demand for warming of the upstairs rooms, the desirability of easy means of heating water, and the fact that many housewives would like central heating although there would be no open fire. Needless to say, the results of a survey of this kind require most careful interpretation, and the answers to questions on subjective factors must be treated with a certain reserve.

1. 2. THE IMPORTANCE OF DOMESTIC HEATING TO NATIONAL FUEL POLICY

FACTORS IN A NATIONAL FUEL POLICY

1. 2. 1. Domestic heating is of direct importance to the individual, but the question is also of the greatest importance to national fuel policy, and must therefore be looked at from the national aspect. Apart from the use, fairly small so far, of hydro-electric power or imported oil, the heating of buildings in this country depends on coal. About one-third of our annual home consumption of coal is used for the heating services of domestic buildings, so that methods of domestic heating should be a major factor in determining fuel policy and in influencing national prosperity. Coke, gas, and electricity are coming increasingly into use for heating. Are the trends in the right direction, and should they be accelerated? Again, if changes are desirable and are coming, what can best be done in post-war building in anticipation of them, so that the change may be facilitated?

DISTRICT HEATING

1. 2. 2. An important possibility is "district heating"—the supply of heat from a single source to a number of buildings. This is established practice in places in the United States, Russia, and Germany, and there are some small examples in Great Britain. District heating has certain obvious advantages, and the possibility of replacing individual heating arrangements in the separate homes or buildings by a system which provides heat "on tap" has to be carefully examined. District heating will form the subject of a separate Report.

Increased national efficiency in all directions is essential if this country is to

keep its place in the world markets, into which it has to enter to a greater extent than others in view of its dependence on imported food supplies. Increased efficiency means wasting less mining labour and less fuel, so enabling the standard of living to rise. It means greater comfort in the home and a smaller drain on the householder's purse. National efficiency is also promoted by any improvement in health, and in so far as better standards of heating conduce to healthy conditions, they may be regarded as a form of national economy.

PRESENT CONSUMPTION OF FUEL IN GREAT BRITAIN AND ABROAD

1. 2. 3. In 1938 there were in Great Britain some 12·5 million dwellings, with about 3·7 persons to each. The quantity of coal used for "domestic" space heating, water heating, and cooking services is estimated to have been about 63 million tons [1] or about 1½ tons per head. With better methods of insulation it should be possible to get higher standards of heating without an increase in this figure. The fact that 1½ tons were used and that a relatively poor standard of warmth was obtained means that the average efficiency of domestic heating in this country is low (probably well below 25 per cent, though it is difficult to give a precise figure because it is not possible to separate the cooking and water-heating from the space-heating load).

A comparison with the fuel consumption in other countries is of some interest. The data collected in Table 1 (1) are based largely on figures given in the *Transactions of the World Power Conference*, 1938 (Vol. IV). The figures for fuel consumption in Germany and the United States refer to the year 1936, and include the whole domestic load for heating, lighting, etc., and, so far as can be ascertained, they include also small commercial consumers. The British data (which exclude lighting but include small commercial consumers) have been supplied by the Ministry of Fuel and Power, and refer to the year 1938.

TABLE 1 (1)

DOMESTIC FUEL CONSUMPTION IN GREAT BRITAIN, THE UNITED STATES, AND GERMANY

		BRITAIN	U.S.A.	GERMANY
Number of households		$12{\cdot}5 \times 10^{6}$	32×10^{6}	18×10^{6}
Population		46×10^{6}	129×10^{6}	66×10^{6}
Thermal value of Fuel (B.Th.U.)	Raw coal, gas,* coke,* anthracite	1740×10^{12}	4045×10^{12}	1267×10^{12}
	Natural gas	—	346×10^{12}	—
	Wood	Negligible	640×10^{12}	254×10^{12}
	Electricity*	101×10^{12}	‡265×10^{12}	‡65×10^{12}
	Fuel oil	†15×10^{12}	185×10^{12}	Negligible
B.Th.U. per house		149×10^{6}	171×10^{6}	88×10^{6}
B.Th.U. per person		40×10^{6}	43×10^{6}	24×10^{6}

* Figures refer to raw coal used in the production of gas, coke, and electricity.

† Includes paraffin.

‡ The figures for domestic electricity consumption in the United States and Germany include current generated by water power and other means as well as coal-burning stations. In the United States 40 per cent, and in Germany about 20 per cent, of the total energy is generated from water power.

[1] Fifty million tons as raw coal, together with coal used for making coke, gas, and electricity for domestic purposes. The figure of 55 million tons given in Post-War Building Studies, No. 1, *House Construction*, was based on earlier estimates, and did not include miners' coal. See Table 14 (1).

EFFICIENT USE AND PROCESSING OF COAL

1. 2. 4. In view of the strictly limited reserves of coal available for special purposes, it would seem reasonable to reserve those coals for the purpose for which they are particularly suited, and not to squander them unnecessarily on other uses for which they are unessential or not suited. This seems desirable both in order to conserve our coal resources and in order to make full and efficient use of coal, thus avoiding waste of labour and capital.

The value of the by-products obtained from the treatment of coal is considerable. The bulk of the products are recovered at gasworks and coke ovens, where by carbonization the coal is broken down into gas, coke, ammonium sulphate, and benzole and coal tar with their many derivatives. Many of these derivatives have a high value in the manufacture of various chemical products and fertilizers. The dyestuffs and plastics industries are important industries which are large users of by-products from coal. Normally when raw coal is burnt directly, the whole of these by-products is lost (except that, with smokeless combustion, they are converted into heat).

OIL FUEL

1. 2. 5. The use of oil fuel for domestic purposes is not, taking the country as a whole, of comparable importance with the domestic use of the other fuels, with which this Report is primarily concerned. Such information as has been supplied to the Committee on the domestic use of oil fuels and of certain gaseous derivatives is given in Appendix 8.

1. 3. CHOICE OF METHODS OF HEATING

Those responsible for the choice of methods of heating of new houses need to make a careful study of the relative costs of the various systems available in any district, taking into account methods of charge for fuel such as the two-part tariff and the costs of appliances. Small users cannot always be expected to have all the data available on which to base a sound decision. The cost of all appliances, such as grates, ranges, and stoves, and also the ancillary building equipment and installations such as flues, chimney stacks, and fuel stores, and gas piping and electric wiring, etc., need to be brought under review if a comparison is to be valid.

In order that the consumer may have reasonable freedom of choice, it is suggested that living rooms and kitchens, and possibly one bedroom, should be provided with flues suitable for solid-fuel appliances (*i.e.* not less than 50 sq. in. in area) and that other bedrooms should be provided with flues having a cross-sectional area of 30 sq. in. so that gas fires may be used if desired. Moreover, to permit freedom of development in the fuel industries, public utility undertakings should be afforded the opportunity of providing gas and electricity in all new houses at the time of their erection. Experience has shown that to make provision for the supply of gas and electricity after the erection of the house is relatively costly and is usually a matter of great inconvenience to the occupier.

In view of the national importance of the right use of coal, it is not sufficient to leave the whole choice of methods of heating to haphazard development. A planned policy, national in scope, is desirable, in order that the industries concerned may direct their efforts into the right channels, and be enabled to organize themselves to meet the large programme ahead.

CHAPTER 2. THE BASIC REQUIREMENTS FOR HEATING AND VENTILATION

2. 1. THE REQUIREMENTS FOR ROOM WARMING

DIFFICULTY OF PRECISE DEFINITION

2. 1. 1. It is notoriously difficult to define the basic human needs for warmth, and every pronouncement made, by however eminent an authority, is liable to arouse controversy. The fact is that people differ in so many ways, that it is only possible to define the desirable conditions of their environment in the broadest terms, realizing that there must be considerable latitude allowed and some call on the individual to adjust himself to his environment. Temperature in the home should be controllable, and people should be instructed how to use and regulate the appliances provided. Some of our recommendations are no more than re-statements of standards already proposed. It should be understood that, in framing the recommendations, the comfort and health of the majority of persons have been the major considerations. Neither of these aspects should be over-emphasized at the expense of the other.

It is possible to have too much comfort, for the body may then lose its power of quick adaptation, which is an essential requirement of normal health. For the most part, outside workers are exposed to conditions in which the body has to adjust itself to temperature changes; the housewife and children, too, are out and about during the day; what is essential is that the family can be warm and cosy when they need to relax. The body heat-control mechanism of the sedentary worker, who spends hours in a centrally-heated office, and an hour or so in a crowded train or tram, might cease to function properly if the home were also kept throughout at a uniform comfortable temperature. The importance of this aspect is endorsed by the Housing Commission of the League of Nations Health Organisation, which expressed the opinion that "... harm may be done to the faculty of adaptation of the human body by the tendency which seems to be growing in some countries for a continuous increase in and a too steady maintenance of the (full comfort) temperature of dwellings."

The maintenance of a good standard of mental and physical health depends on many factors, including heating and ventilation. There is a minimum standard of heating and ventilation below which health would suffer. There is also a higher and more desirable standard introducing a degree of comfort which should be capable of attainment by the occupants of post-war houses. (The actual standard chosen will vary widely and must be variable so as to suit the individual.)

Clothing affects the feeling of bodily warmth since it influences skin temperature, on which the feeling of warmth and comfort depends. If houses were properly warmed, the amount and weight of clothing needed indoors would be less, and probably this is the healthier condition as it allows for greater response of the skin. There is no doubt scope for further study in this direction, but for the time being, it is considered in providing the average temperature condition in the building, that the individual should if necessary vary the amount of clothing worn to suit his or her needs.

A matter which is often overlooked is that clothing which is put on to protect from cold conditions or for outside wear should be warm and dry; when taken out of a cold and damp cupboard it takes time to be heated up by the body.

The scientific definition of "comfort" is by no means a simple matter. On many of the factors involved, scientific information is incomplete, and inevitably the views here expressed are tentative rather than final.

HEAT LOSS FROM THE HUMAN BODY

2. 1. 2. Nature has provided man with an elaborate system of heat-regulating devices, which enables the temperature of the bulk of the body to be maintained at a nearly constant temperature of about 98° F. Heat is continually being lost from the body to cooler surroundings by convection to the contiguous air, by evaporation of moisture from the skin, by respiration, and by radiation to the surroundings. The total loss from a person sitting in a reasonably warm environment is about 400 B.Th.U. per hour, and of this, about 20 per cent is lost by respiration and evaporation, the remainder being dissipated by radiation and convection. The loss by convection and radiation together increases with a fall in temperature of the air and surroundings, and also with an increase in the air velocity. The evaporation loss depends on the humidity of the air and its velocity, but at all ordinary room-temperatures (below about 80° F.) the evaporation loss remains substantially constant, except at extremes of humidity. In very warm environments or when a large amount of physical work is done, the heat lost by radiation, convection, and respiration is insufficient to balance the heat production, and sweating is then induced. For a sedentary person who has become adjusted to an environment, "the subjective feelings of warmth are related to the combined heat loss by radiation and convection, even though these sensations may often be quite independent of the total heat loss." [1] This is not the case when a person suddenly changes his environment, or ceases to do physical work, when his feelings of warmth and comfort are related to his previous activity as well. It must be remembered that the heat production of the body rises rapidly with increased activity.

Extreme conditions of humidity would affect the feeling of warmth and comfort, but over the range of humidities normally existing in warmed rooms in Britain the changes in humidity have little effect on the feeling of warmth of sedentary persons. At a temperature of 70° F., a fall in relative humidity from 50 per cent to 33 per cent (a change of 17 per cent R.H.) may be compensated by a rise of only 1° F. in the temperature. At 60° F. the effect of changes of humidity is even less.

EQUIVALENT TEMPERATURE

2. 1. 3. Many attempts have been made to devise an instrument which will record in a single index some or all of the four factors—air temperature, air movement, humidity, and radiation from the surroundings—which affect the feeling of warmth. In 1931 a joint Committee of the Medical Research Council and the Department of Scientific and Industrial Research was set up to consider this and other matters of common interest to physicists and physiologists working in this field. The Committee adopted as the standard instrument for use in this country the eupatheoscope devised by Dufton. The eupatheoscope does not take account of changes of humidity, but does take account of the other three factors. It yields measurements of warmth in terms of "equivalent temperature." The equivalent temperature is in effect an index of the rate of cooling of the human body in an environment, and is, therefore, an index of warmth. It follows that the equivalent temperature of two environments may be the same even though the air temperature, air movement, and radiation may be quite different.

For scientific purposes equivalent temperature is defined as follows: "The equivalent temperature of an environment is that temperature of a uniform enclosure in which a black cylinder of height about 22 in. and diameter about $7\frac{1}{2}$ in. would lose heat at the same rate as in the environment under consideration, the surface of the cylinder being maintained at a temperature which is a precise function of the heat loss from the cylinder and which in any uniform enclosure

[1] Bedford, *Warmth Factor in Comfort at Work.*

is lower than 100° F. by two-thirds of the difference between 100° F. and the temperature of that enclosure."

The interpretation of these apparently complicated conditions is that the surface temperature of the cylinder is substantially the same as the temperature of the outer surface of normal clothing worn by a human body in the same environment. Thus in an enclosure at 62° F., the surface temperature of the cylinder is 75° F. —this is about the generally accepted temperature of the outer layer of clothing worn by a person in a room at normal room temperature.

A confirmation of the validity of the method was obtained by Bedford, who made a detailed comparison of the various scales of warmth which have been proposed from time to time; and he found that the equivalent temperature scale gave the best correlation with the warmth sensations of a large number of subjects.

The feeling of human comfort (as distinct from warmth) is dependent also on influences other than the rate of gross heat loss from the body, and many of the factors are very imperfectly understood. A satisfactory equivalent temperature can be recorded in circumstances where one side of the body would be uncomfortably cold and the other uncomfortably hot. Thus the direction, as well as the amount, of radiation and of air movement is of importance.[1]

Not all radiation is of the same character, and much work has been done, though with inconclusive result, on the skin penetration of heat of certain wavelengths, some of which are more inclined than others to cause discomfort by scorching and by glare.

The causes of the sensations described as "freshness" or "stuffiness" still remain somewhat obscure, although temperature gradient and other factors are believed to have some effect on these sensations (see 2. 1. 5. 3–5).

Equivalent temperature may also be estimated by more portable apparatus, such as the Aitken thermometer in conjunction with a kata-thermometer. A description of these instruments and their use for measuring equivalent temperature can be found in Appendix 2.

The point of practical importance is that these methods of measurement of equivalent temperature are sensitive to such factors as cold draughts, cold walls, cold floors, etc., as well as to the heat received from the various sources which can be used for warming rooms. For the final evaluation of the effectiveness of a method of heating in the room in which it is to be used, the method is indispensable.

THE DESIRABILITY OF BACKGROUND HEATING IN A DWELLING

2. 1. 4. Apart from the necessity of providing warmth to render conditions in the home comfortable, it is desirable to provide against excessive chilling of the structure of the house, which causes condensation of moisture on walls, furnishings, and household linen. Such condensation most frequently occurs when the outside temperature and humidity rise suddenly after a spell of cold weather. It is probable that a considerable amount of the trouble may be avoided if the temperature inside the house is prevented from falling below about 45° to 50° F. by providing a moderate degree of continuous warmth or background heating.

The average outdoor temperature remains below 45° F. for about four or five months; and, as it is usually estimated that the average inside temperature of an unheated building is a few degrees higher [2] than the average outside temperature, heating to keep the temperature above 50° F. would be required for only about four or five months of the eight or nine months of the heating season. In practice, this period may be considerably reduced by the casual heating of the house due to heat losses from apparatus, such as hot-water systems, and to the general warming

[1] Yarnold has modified a eupatheoscope in an attempt to take account of the direction of radiation (" split eupatheoscope ").

[2] See 3. 1. 1. 1.

effect of heating even one room only. It would not be possible, however, to dispense entirely with some form of heating, unless the house is very well insulated. A comparison of the number of degree-days [1] for various internal temperatures is instructive: for an internal temperature of 50° F., the number of degree-days at Kew amounts to 600, compared with 3750 for an inside temperature of 65° F.

Another argument for a certain amount of general heating in cold weather is that the housewife should not necessarily have to do her work about the house in unheated rooms in the depth of winter. A temperature of 50° to 55° F. would prevent a sensation of chill.

Background heating in a house has further advantages: the risk of freezing of water pipes is reduced, and comfortably warm conditions are reached much more quickly when required, than if the house is allowed to cool down nightly. The reduction of the pre-heating period (*i.e.* the time required to bring the room to a comfortable temperature) would go some way towards off-setting the extra fuel required to maintain the temperature suggested.

2. 1. 5. DESIRABLE WARMTH CONDITIONS IN LIVING ROOMS

2. 1. 5. 1. *Equivalent Temperature.* An equivalent temperature of about 65° F. has generally been considered a suitable standard for this country for warmth when sitting for lengthy periods. Most people would then feel comfortably warm within the range 62° to 66° F. equivalent temperature, and the variation should not in general exceed the range 60° to 68° F., for the upper and lower limits represent rather extreme conditions. When the living room is not continuously occupied or when active housework is being done, a lower equivalent temperature, say 50° to 55° F., is enough, and during the night the temperature can be allowed to fall to 45° to 50°.

2. 1. 5. 2. *Air Velocity.* Although a reasonable temperature is essential, there are a number of other factors which affect the warmth and comfort of the individual. All these factors, discussed in paragraphs 2. 1. 5. 2 to 2. 1. 5. 8, apply as well to the other rooms of a house as to the living room. Complaints of cold feet are common in sitting rooms, and these are due either to excessive air-movement across the floor or to an excessive temperature difference between floor- and head-level. It has been found that in winter, currents of air whose temperature is at or slightly below the average air temperature, and moving with a velocity greater than about 40 ft. per min., impinging on the unclad or lightly clad parts of the body, such as the face and the ankles, led to discomfort owing to local chilling. It should be noted that much higher velocities can be tolerated for short periods and, when felt on the face, provide a useful stimulus to the body. It is concluded, therefore, that in winter the average air velocity in the breathing space and near the floor should not exceed 20 ft. to 40 ft. per min., although a variation of velocity about this value is distinctly useful. This is a little greater than the air velocities normally found in the centre of a warmed room, but not nearly as high as the objectionable draughts along the floor between the door and the fire which occur with some methods of heating and some types of plan. Velocities as high as 75 ft. to 100 ft. per min. have been recorded in some positions.

A fully controlled system of ventilation is at present unlikely to be practicable in the majority of premises under consideration, and reliance must be placed on better methods of construction to avoid ingress of air where not required and on the general practice of opening a window to air a hot room—a practice which is to be commended as an aid to health and comfort.

2. 1. 5. 3. *Temperature Gradient.* An excessive positive air-temperature gradient between floor- and head-level is undesirable, for if then the temperature at head level is comfortable the temperature near the floor is too low and the feet will

[1] See 3. 1. 1. 1.

be cold. Conversely, if the air at floor level is high enough for comfort, the head will be too warm. The temperature at head level should not, for comfort, exceed by more than about 5° F. the temperature at floor level. Further, in low rooms such as those usually met with in dwellings, the air temperature 6 in. to 1 ft. below the ceiling should not be more than about 8° to 10° F. higher than floor-level temperature. If the difference is greater than this, the layer of hot air near the ceiling may cause a feeling of stuffiness. For high rooms (say 12 ft. or more) this temperature-difference could be greater without causing discomfort.

2. 1. 5. 4. *Radiation.* Too much radiation on the head causes discomfort and tends to a feeling of stuffiness, but the question has not arisen in domestic heating in the past, as high-level heat sources have rarely been used. The conclusion is that ceiling heating should not be used as the sole source of heat in rooms much less than 12 ft. high. Floor heating on the other hand is advantageous in these respects.

2. 1. 5. 5. *Stuffiness.* Stuffiness may be experienced when the air temperature is much greater than the mean radiant temperature of the surroundings; and conversely, when the air temperature is less than the mean radiant temperature a feeling of freshness is noticed (probably owing to the greater effect of variations of air movement on the convection heat loss from the body when the air temperature is low). In the latter case, too great a difference should however be avoided, as otherwise discomfort due to draughts would arise.

2. 1. 5. 6. *Heating by Radiation plus Convection.* With many heating systems combining convection and radiation from a low-temperature source, such as a closed stove or a hot-water radiator, the radiation is usually of low intensity, and in such cases the mean radiant temperature will not be very different from the mean wall temperature. It is suggested that the aim should be to establish a mean radiant temperature about 3° F. above the air temperature. Comfortable conditions would be obtained with an air temperature from 63° to 67° F., and mean radiant (wall) temperature from 66° to 70° F., giving an equivalent temperature of 62°–66° F.

2. 1. 5. 7. *High-Temperature Radiant Heating.* When high-temperature radiant sources are used, such as the open coal or coke fire, and gas or electric fires, the radiation into the room is not uniform, since the radiant sources are small and they give a non-uniform beam of high intensity. Unidirectional radiation with a mean horizontal component of 6 or 7 B.Th.U./sq. ft./hr. produces a rise of approximately 1° F. in equivalent temperature. It has been found that people were fairly comfortable at an air temperature of 55° F., provided that sufficient radiation was felt (75 B.Th.U./sq. ft./hr. in a unidirectional beam). At lower air temperatures, the people felt scorched in front and cold at the back. The figure of 55° F. air temperature should therefore be regarded as a minimum. In order to obtain a comfortably warm room with small high-temperature sources of radiation, the air temperature should be about 58° to 62° F., and the wall temperatures the same, and there should be additional (unidirectional) radiation up to about 40 B.Th.U./sq. ft./hr. on the surface of the body. This amount of radiation is readily obtained with coal, gas, or electric fires, or indeed with any form of radiant heating, and the equivalent temperature will be from 62° to 66° F., as in the previous case.

2. 1. 5. 8. *Convection Heating.* When the heating of a room is by convectors alone, the wall temperature is usually about 1° F. lower than the air temperature. It is, however, preferable, and gives a feeling of greater freshness to most people, if convection heating is used to bring the air- and wall-temperatures to say 55° to 60° F. (*i.e.* background heating, in which the whole room is warmed to a temperature somewhat lower than the comfortable level) and a radiant source is used to "top-up" to the equivalent temperatures of 62° to 66° F. required for adequate

warmth; and this will also raise the air- and wall-temperature above the 55° to 60° F. achieved by convection heating.

DESIRABLE WARMTH CONDITIONS IN BEDROOMS

2. 1. 6. There is some conflict of opinion as to whether in the ordinary way bedrooms should be heated, provided sufficient bedclothes are available, because the actual temperature outside the bed, provided it is not too high, is not so important as that inside, which, after the bed has been slept in for a while, becomes fairly constant at some temperature between 80° and 90° F.—in fact not very different from the skin temperature under clothing. The disadvantages of the completely unheated room, however, are so considerable that there can be little real doubt on the matter. If there is no heat at all it is too much to expect of the average person that he will ventilate the room properly, and, moreover, the British climate and the porous wall construction prevalent before the war make it likely that an unheated room, and the clothing and furniture stored in it, will be damp in winter, especially in the west.

These considerations could be met by providing facilities for obtaining an equivalent temperature of 50° to 55° F. during dressing and undressing and when the room is occupied during the day, and for preventing the temperature from falling below 45° to 50° F. during the night.

Two other features which are desirable may be mentioned. One is that, in case of illness, there should be means of warming at least one bedroom to an equivalent temperature of 65° F., at as low an extra cost as possible and with the minimum of labour and inconvenience. The other is that the bedroom should be capable of being warmed up quickly, so that it can be used as an additional room for study, children's homework, etc. (See paragraph 3.1.4.2.)

DESIRABLE WARMTH CONDITIONS IN KITCHENS

2. 1. 7. When a kitchen is also used as a living room the conditions laid down in 2. 1. 5 for living rooms should be provided. Since occupation of a kitchen, entirely separate from a living room, is rarely continuous for long at a time, and since the housewife is usually moving about, it is not necessary or desirable to provide as high a temperature as for the living room, and an equivalent temperature of about 60° F. would be adequate under working conditions. The temperature at night may be about 45° to 50° F.

In view of the many operations carried out in a kitchen that may contribute to its heating, it is impossible to estimate the heat which need be supplied specifically for space heating. It should, however, be possible to obtain sufficient heat for comfortable working conditions when cooking, laundering, or ironing are not in progress.

The high humidity liable to be set up in a kitchen is a special problem, for it will probably be difficult to keep the humidity below 70 per cent at all times. Adequate ventilation, which should preferably be controllable, is needed to prevent an increase over this amount.

DESIRABLE WARMTH CONDITIONS IN HALLS, PASSAGES, ETC.

2. 1. 8. There is no need to heat halls, passages, bathrooms and w.cs. to the equivalent temperatures needed for living rooms or kitchens. They are only occupied for short times, and during the day an equivalent temperature of 50° to 55° F. should be adequate to prevent a sensation of chill in moving about the house. A night temperature of 45° to 50° F., as for the other rooms, would keep the house warm. The air velocity requirements are similar to those for the living room. It is very important to note that it will be impossible to keep the hall and passages warm and comfortable if there is a strong draught under the front door.

SUMMARY OF DESIRABLE WARMTH CONDITIONS

2. 1. 9. Owing to the wide variety of personal tastes and habits it is not advisable to lay down the desirable standards of temperature, etc., for different rooms too rigidly. It is only recommended that provision should be made to enable the occupants to attain the suggested standards if they so desire.

Recommended ranges of equivalent temperatures, air temperature and humidity are summarized in Table 2 (1) below:

TABLE 2 (1). STANDARDS OF WARMTH RECOMMENDED FOR THE ROOMS OF A HOUSE

The whole house should be maintained at a temperature of at least 45° to 50° F.

Living Room	
Equivalent temperature during occupation	62°–66° F.
Thus for heating systems with high-temperature radiant source:	
Air temperature (at head level)	58°–62° F.
Mean surface temperature	58°–62° F.
Unidirectional radiation	40 B.Th.U./sq. ft./hr.
And for other systems of heating:	
Air temperature	63°–67° F.
Mean radiant temperature [1]	66°–70° F.
Air-temperature difference (floor to head level)	0°–5° F.
Relative humidity (this includes most normal conditions)	30%–65%
Note: There should not be excessive radiation to the head.	
Bedrooms	
Equivalent temperature (during day and periods of dressing and undressing)	50°–55° F.
Relative humidity (this includes most normal conditions)	30%–65%
Kitchens	
Equivalent temperature during daytime	about 60° F.
Relative humidity	less than 70%
Halls, Passages, w.cs., etc.	
Equivalent temperature during daytime	50°–55° F.
Relative humidity (this includes most normal conditions)	30%–65%

2. 2. THE REQUIREMENTS FOR VENTILATION OF ROOMS

2. 2. 1. NECESSITY FOR VENTILATION

"Ventilation" is defined, for the purposes of this Report, as the process of changing the air in a room: the vitiated air, containing the products of respiration,

[1] *Note:* The mean radiant temperature may be taken as the sum of the products (surface temperature and surface area) taken over the whole of the room, divided by the surface area.

bacteria, body odours, cooking odours, and tobacco smoke, should be continuously withdrawn and should be replaced by fresh air.

In this country, over many months of the year, adequate ventilation can be obtained by opening windows, but in winter this may lead to needless expenditure of fuel unless properly regulated. Properly designed windows will reduce such expenditure to a minimum, and under practically all atmospheric conditions will allow the ingress of the fresh air required without discomfort. There is, of course, the difficulty that some people may keep their windows permanently closed even with improved designs. If some form of controlled or semi-controlled system becomes practicable for the small house, it might be used with advantage. The flues mentioned in 1. 3., although not required by central heating or electric radiators, will, provided they are kept open, ensure that the vitiated air is removed.

Ventilation is essential for four main reasons, as follows:

a. To prevent unduly high concentration of carbon dioxide and moisture, and depletion of the oxygen content of the air.

b. To prevent concentration of bacteria-carrying particles.

c. To prevent undue concentration of body odours.

d. For the removal of products of combustion.

2. 2. 1. 1. *Carbon Dioxide Concentration.* Even in the worst ventilated rooms the content of carbon dioxide rarely rises above about 0·5 to 1 per cent. Indeed, the amount of air required to keep the carbon dioxide concentration down to 1 per cent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects—the oxygen content may vary quite appreciably without noticeable effect if the carbon dioxide concentration is unchanged. The concentration of carbon dioxide or of oxygen is thus not sufficiently critical to provide a basis for fixing rates of ventilation.

2. 2. 1. 2. *Bacterial Concentration.* Investigators have attempted to define ventilation requirements in terms of what is required to prevent the spread of infection, but this work has not yet been carried to a conclusive stage. Infective particles differ considerably in size, and the smaller ones are apt to accumulate if ventilation is insufficient. A ventilation rate of 4 to 6 air changes per hour is effective in greatly reducing the number of these smaller particles. The larger particles fall at a considerable rate, but this effect is in part offset by the re-dissemination of particles that have fallen to the floor. Owing to their high rate of fall, and to their high rate of production, they are much less affected than the smaller ones by ventilation at normal rates. The same applies to an even greater extent to the coarse particles projected directly from one person to another in sneezing, coughing, and conversation. The concentration can be but little affected by any reasonable rate of ventilation. Thus reliance must be placed on cleanliness of house and person. Re-dissemination may be reduced by the use of certain oils and bactericidal dressings on the floors. Various bactericidal agents, such as ultra-violet radiation or disinfectant spray, may be used, some of them in conjunction with air-conditioning equipment.

2. 2. 1. 3. *Body Odour.* Several English research workers used body odour concentration as the index of the purity of the air. Recently, American research workers have studied this aspect in more detail and formed the opinion that body odour is a suitable criterion for ventilation, and that when it is perceptible headaches may result, and people subjected to the odours may lose their appetites. The amount of fresh air was, therefore, estimated on the basis of that necessary to keep the space occupied free from noticeable odours, and this work has been used in the present Report to determine the requirements for ventilation.

2. 2. 1. 4. *Products of Combustion.* With certain forms of heating systems, products of combustion may be discharged into the room. This is the case with flueless gas appliances of all types and sometimes with stoves, in which carbon monoxide may be formed under certain conditions.

MINIMUM STANDARD OF VENTILATION

2. 2. 2. The rate of ventilation is commonly expressed by giving a figure for the number of complete air-changes per hour in each room, assuming by one air-change that a quantity of air has entered and been withdrawn equal to the total volume of air in the room. To estimate the number of air-changes required for any one room, it is necessary to assume the number of persons using the room and the quantity of air required per person.

The exact minimum amount of ventilation required for health cannot be accurately determined, but after considering the available evidence on the subject the Committee has adopted a figure of 600 cu. ft. per hour per person as the normal minimum requirements for the purpose of this Report.

The rate of ventilation of rooms affects both the comfort of the occupants and the fuel consumed to keep the rooms warm. Excessive ventilation gives rise to objectionable draughts near doors, windows, and open fireplaces. Hence the standards recommended, which are minima for winter conditions, should not be much exceeded in winter, otherwise the cost of heating will be significantly increased.

RECOMMENDED STANDARDS OF VENTILATION IN LIVING ROOMS

2. 2. 3. In normal living rooms, of the type found in local authority housing, there is usually about 45 sq. ft. of floor space per person, corresponding to about 360 cu. ft. of air space per person. These quantities represent about the minimum consistent with giving accommodation for furniture and space to move about in. 600 cu. ft. of fresh air per hour per person should be sufficient to prevent an undue concentration of objectionable odours, and is suitable for persons of average cleanliness. In a normal living room of about 1500 cu. ft. capacity, about $1\frac{1}{2}$ air-changes per hour will therefore be necessary for the needs of a family of four. It may be noted that an air-change of at least this value will usually be obtained in a room with a normal chimney with any method of heating in operation, provided the flue is not restricted. (See, however, Chapter 8.)

Experiments show that in ordinary rooms with this rate of air-change, the air velocity near the middle of the room will be between 10 ft. and 20 ft. per min. when heating is in operation.

RECOMMENDED STANDARDS OF VENTILATION IN BEDROOMS

2. 2. 4. For bedrooms the minimum fresh air supply should be 600 cu. ft. per hour per person.

RECOMMENDED STANDARDS OF VENTILATION IN KITCHENS

2. 2. 5. Large quantities of air are needed to remove the steam, heat, and fumes generated in cooking and washing. It is probably almost impossible to prevent the humidity and temperature rising considerably during cooking and washing periods unless forced ventilation is provided.

When only moderate amounts of steam or fumes are being generated, a ventilation rate of about 1000 cu. ft. per hour would be enough. This corresponds to about two air-changes per hour in an ordinary kitchen of the kind found in modern local authority housing, and will be roughly sufficient for the requirements of a kitchen in which cooking is done for a family of not more than 6 persons.

The smell of cooking and the steam from laundry should not be allowed to permeate the whole house, and the means to avoid this are dealt with in Chapter 8.

RECOMMENDED STANDARDS OF VENTILATION IN HALLS

2. 2. 6. The period of occupation of halls and passages is very short, and one air-change per hour would be ample. This ventilation requirement is adequately met by normal air infiltration round doors, etc., and in fact the problem is to prevent an excessive amount of ventilation due to accidental air leakages.

RECOMMENDED STANDARDS OF VENTILATION IN BATHROOMS AND W.CS.

2. 2. 7. Considerable ventilation of bathrooms and w.cs. is desirable, especially after use, and the equivalent of at least two air-changes per hour should be provided.

SUMMARY OF RECOMMENDED MINIMUM RATES OF VENTILATION

2. 2. 8. The recommended minimum standards for the various rooms of a dwelling during the periods of occupancy are summarized in Table 2 (2).

TABLE 2 (2)

RECOMMENDED MINIMUM STANDARDS OF VENTILATION IN DWELLINGS

ROOM	AIR SUPPLY, PER HOUR
Living room (4 persons)	2400 cu. ft.
Bedroom (2 persons)	1200 ,,
Bedroom (1 person)	600 ,,
Kitchen (cooking for not more than 6 persons)	1000 ,,
Halls and passages	1 air-change
Bathroom and w.cs.	2 air-changes (or more)

The tabulated standards are based mainly on the results of work on the ventilation needed to prevent odours from reaching "unpleasant" strength, and partly on general experience in kitchens, bathrooms, etc. It was considered that though the odours themselves might not be injurious, they are unpleasant and indicate conditions which might be unhealthy. The importance of cleanliness of the person is clear, and it is thought that improved conditions may be looked for by further research and social study, to which encouragement should be given. The relation of ventilation to the general cleanliness of the house and the necessity for removing dust and dirt and other sources of infection has also been indicated. Under present conditions, standards of ventilation lower than those tabulated cannot be recommended.

It is important that the incoming air used for ventilation should be fresh and uncontaminated by dust from floors or by soot and smoke, and it should not be drawn from regions where the air is already charged with organic matter (*e.g.* stables, etc.).

2. 3. THE REQUIREMENTS FOR DOMESTIC HOT WATER

IMPORTANCE OF ADEQUATE HOT WATER

2. 3. 1. An adequate supply of hot water is considered to be a necessity for any house. No other factor is so important for the encouragement of decent

standards of cleanliness in the house and person. The Committee have been informed tha in one estate of 5000 houses it was formerly necessary to treat 2 or 3 houses every month for bug infestation; but after the installation of an adequate hot-water supply (from central sources) and a number of pit-head baths there has been not more than one case a year. This instance shows that an ample supply of hot water is of great help to the housewife who is trying to eradicate bugs, though it is not of itself sufficient to eliminate the pest.

It is extremely difficult to estimate either the requirements of a household for hot water or the use that will be made by an average family of a convenient supply of hot water when it is available. In making provision for this service, it is necessary to avoid the extremes which lead to an inadequate supply for the more liberal user on the one hand, or an excessive installation and running cost for the less liberal user on the other hand. The recommendation adopted is based upon reasonable requirements for a family of four persons—two adults and two children.

TOTAL HOT WATER REQUIREMENTS

2. 3. 2. The installation should be capable of supplying 250 gallons of water at 140° F. weekly. Facilities should be provided to give a supply at 140° F. for washing dishes and for laundry purposes, and a means of conveniently bringing about 7 gallons of water to the boil; cold water may be addded when necessary for other purposes such as baths and washing.

The above quantity of water would provide approximately sufficient hot water for a total of 7 full hot baths a week, for 10 washes per day (at a washbasin), for normal washing-up requirements, for 10 gallons a week for house cleaning, and for 50 gallons a week for laundry.

2. 4. THE REQUIREMENTS FOR COOKING

In the average house, provision should be made so that meals can be cooked for 6 persons, in order to allow for the presence of occasional visitors. In addition, facilities for quick boiling of water are also required.

CHAPTER 3

FACTORS AFFECTING THE AMOUNT OF HEAT NEEDED IN DWELLINGS TO MAINTAIN THE CONDITIONS DEFINED IN CHAPTER 2

3. 1. HEAT REQUIREMENTS FOR ROOM WARMING

In Chapter 2 recommendations have been made for the heating and ventilating conditions which should be aimed at in modern dwellings. The next step is to ascertain the amount of heat required to maintain these conditions. The required heat input is obviously that needed to make good the heat losses from the structure when the conditions are maintained.

It is not possible within the present Report to deal exhaustively with all possible structural combinations which might be used in new housing. The necessary data are given in this Report, however, so that the heat requirements of a wider range of alternative proposals may be calculated.

3. 1. 1. FACTORS INFLUENCING HEAT LOSS FROM BUILDINGS

The heat losses from a heated building are determined by several factors, which include:

a. The internal temperature.
b. The local climatic conditions.
c. The degree of exposure of the building.
d. The orientation of the building.
e. The structure of the building.
f. The rate of air-change for ventilation.
g. The type of heating system used.

(The heat wastage from an appliance, as distinct from the building, is more properly considered with the efficiency of the appliance.)

Before considering in detail the amount of heat needed to warm a typical house and flat, it will be convenient to discuss in general terms the broad effect of each of the above factors.

3. 1. 1. 1. *Internal Temperature and Climatic Conditions.* The influence of the internal temperature and the local climatic conditions on the heat loss from buildings cannot be considered separately. The designer of the heating installation of the building is concerned mainly with the maximum heat requirement, for he has to see that the installation is large enough to give adequate warmth during the coldest period. He must also determine the most efficient and economical ways of heating dwellings over the whole heating season, and estimate what the costs will be.

The maximum heat requirement (and hence the size of the appliance) is usually calculated on the assumption that the inside temperature is maintained at 65° F. against an outside temperature of 30° F. It is obvious, however, that on such an assumption no estimate of the annual heat requirement in a normal season can be made. To do this, account must be taken of the variation of the outside temperature throughout the year, and the heat requirement "integrated" day by day over the season. This is most conveniently done by the use of the "degree-day."

It has been found with central heating plants that the fuel required to maintain a given temperature in a room follows closely the curve showing the difference between the maintained temperature and the mean daily outside temperature (*i.e.* the average over 24 hours) even if the boiler is banked at night. (The correlation between fuel consumption and average outside temperature during the heating period each day is not so close.) In an unheated house the inside air temperature is, on the average, a few degrees higher than the outside temperature (due probably to the solar heat and other gains), and a series of observations by Andrew and Barron showed that this excess was about 5° in their experiments. In other words, when the outside temperature is T° F. no fuel is required to maintain a temperature of (T+5)° F. inside the room. It is necessary therefore to know how much and for how long the temperatures in a given district are below T° F., which may be termed the "base" of the calculation.

The existence of one "degree-day" implies that the mean outside air temperature for one day is 1° below the base temperature. For any one day, there exist as many degree-days as there are degrees difference between the base temperature and the mean daily outside temperature when the latter is below the base temperature. The annual total of degree-days is the sum of the degree-days for all days of the year; unless otherwise stated, the number of degree-days is always understood to be the annual total.

The number of degree-days for any locality can be calculated from information

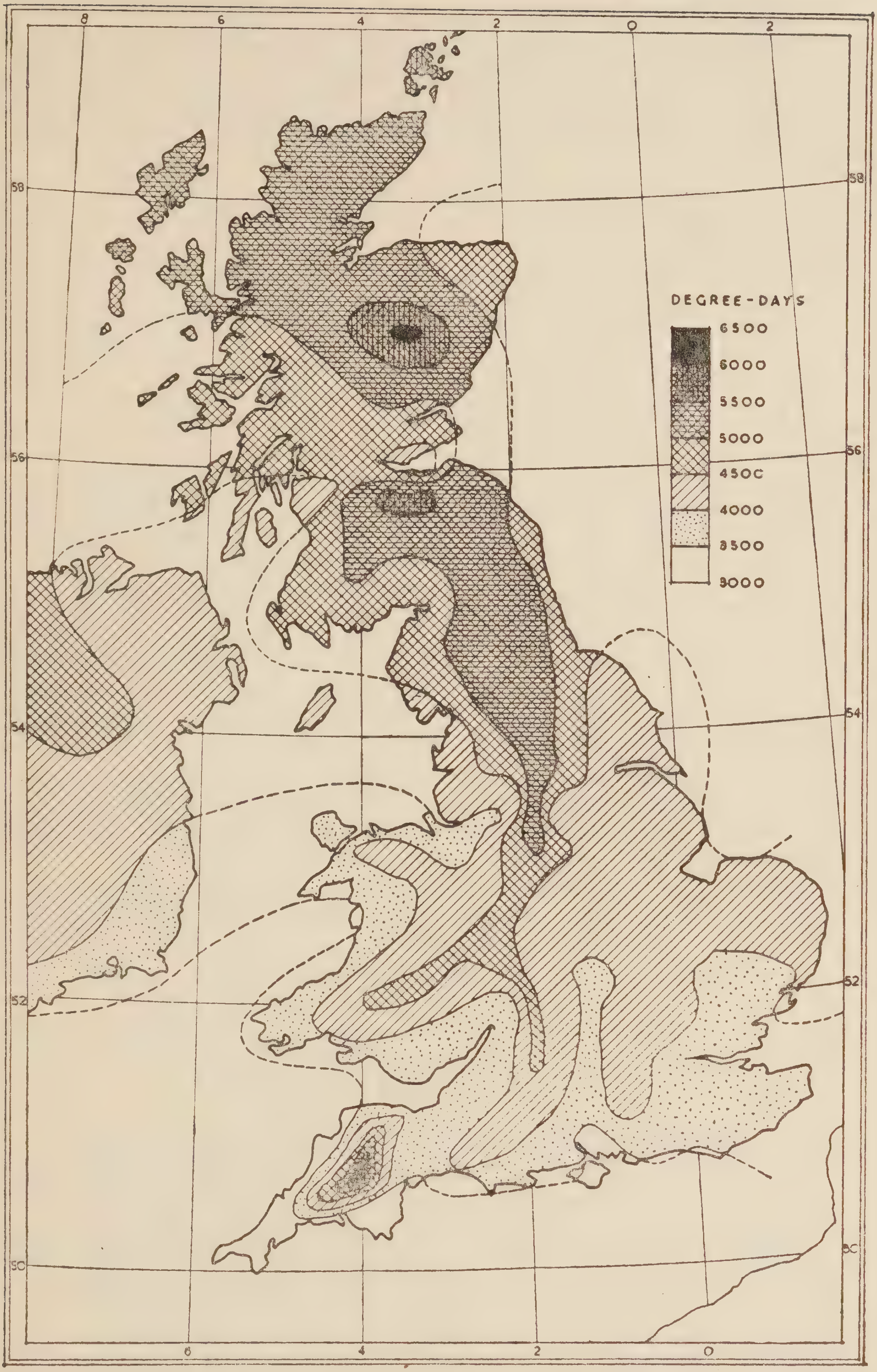

FIG. 1. BRITISH DEGREE-DAYS
TO A BASE TEMPERATURE OF 60° F.
(After Dufton)

in the *Book of Normals*,[1] and Fig. 1 shows the normal British degree-days for Great Britain and Northern Ireland, using a base temperature of 60° F. The number of degree-days for various room temperatures for Newcastle and London (chosen as examples of the northern and southern parts of the country) are given in Table 3 (1).

TABLE 3 (1)

BRITISH DEGREE-DAYS FOR NEWCASTLE AND LONDON

AIR TEMPERATURE OF ROOM ° F.	BASE TEMPERATURE ° F.	DEGREE-DAYS	
		Newcastle	London
65	60	4750	3750
60	55	3100	2400
55	50	1800	1400
50	45	750	600

A glance at the Table shows how appreciably greater—about 25 per cent in this case—is the heating load (as indicated by the number of degree-days) in the northern (and colder) districts. It also shows that the consumption of fuel will increase very rapidly as the inside temperature required is increased.

The degree-day map (Fig. 1) presents a broad picture of the variation of temperature conditions over the whole country. It is known, however, that some purely local variations occur: Rickmansworth, for instance, is recognized as being colder than many of the surrounding districts. This is an example covering a somewhat wide area; but similar differences may occur between sites less widely separated. If possible, therefore, some account of such "micro-climatological" factors should be taken in choosing the sites of new housing development.

3. 1. 1. 2. *Exposure.* The heat losses from a building depend on the severity of its exposure, in which respect wind plays the most important part. Three degrees of exposure have been distinguished by the Institution of Heating and Ventilating Engineers (*Computation of Heat Requirements for Buildings*):

"Sheltered" includes the first two storeys above ground of buildings in towns.

"Normal" includes most suburban and country premises and the 3rd, 4th, and 5th storeys of buildings in towns.

"Severe" includes 6th and higher storeys of buildings in towns, and buildings exposed on hill sites, the coast, or riverside.

If normal exposure is taken as a basis of comparison, the losses from a house on a sheltered site are from 5 to 10 per cent less; and the losses from a house with a severe degree of exposure are from 10 to 15 per cent more.

3. 1. 1. 3. *Orientation.* When the sun shines on a window, heat is transmitted both by radiation and conduction through it into the building, and this solar heat gain will to some extent counterbalance the heat lost in other ways. Solar heat gain may be quite appreciable, as is shown by the fact that in winter the quantity of heat falling on a vertical surface facing south may reach 150 to 200 B.Th.U./sq. ft./hr. The effect of solar radiation falling on walls and roofs is less marked than of that falling on windows, as only the conducted heat reaches the interior of the building. The aggregate effect on a building is, however, appreciable.

The effect of solar radiation is naturally least on north-facing surfaces, but even here, the diffuse radiation on sunny days in winter has been shown to have a small effect on the amount of heat required to warm a room.

It has been found, in one case investigated, that over the whole heating season

[1] See Bibliography.

a room facing north required 17 per cent more heat than a similar room facing south, the differences being least in midwinter and greatest in March and April.

These considerations affect the planning of the house: for economy of heating the living room should face south and possibly the kitchen also; and in the case of the "through" living room, the larger windows should face in this direction.

3. 1. 1. 4. *Structure of Building.* The heat loss through the building structure depends on the materials used and on the workmanship, and on the temperature difference between inside and outside.

The thermal transmittances or heat transmittance coefficients (denoted by the symbol U) of a wide variety of building materials and structures have been determined experimentally, and tables of some of these coefficients are given in Appendix 3.

The value of U used should always be that appropriate to the exposure and orientation of the part of the structure considered. The heat loss through a particular part of the structure may then be obtained by multiplying the thermal transmittance by the area of that part of the structure and by the difference in the air temperature on the two sides of the structure. Other things being equal, the heat loss through the structure is greater, the larger the value of the thermal transmittance. Hence in order to keep the losses to a minimum, materials or methods of construction which have a low thermal transmittance should be used where possible.

It has been noted that the heat loss from a part of a structure depends on the area of that part. For a given volume, the area of the walls of a cubical building is less than the area when the building is more elongated. Consequently, the heat loss is smaller for the cubical building.

3. 1. 1. 5. *Ventilation.* Sufficient heat must be provided to warm the cold air entering the room for ventilating purposes. The heat in the warm air removed is lost. At normal temperatures, about 0·019 B.Th.U. are required to raise the temperature of 1 cu. ft. of air by 1° F. The amount of heat required for warming the ventilating air may thus be calculated. Excessive ventilation is very wasteful of heat. With proper installations it is not difficult to control the ventilation so as to obtain approximately the recommended amount. With poor installations where control is absent, the rates may be much higher. Table 3 (2) gives the results of some experiments in a room with an ordinary coal fire flue, using different methods of heating.

TABLE 3 (2)

EFFECT OF THE VENTILATION PRODUCED BY DIFFERENT METHODS OF HEATING, ON THE HEAT REQUIREMENTS OF A WARMED LIVING ROOM

TYPE OF HEATING, WITH OPEN FIREPLACE AND NORMAL FLUE	RATE OF AIR-CHANGE		HEAT REQUIRED PER HOUR TO WARM VENTILATING AIR (B.Th.U. per °)
	cu. ft./hr.	Air-changes per hour	
Coal fire	7000	4·5	133
Gas fire	4800	3·1	91
Electric fire standing on hearth under a flue	4200	2·7	80
Hot-water radiators	3100	2·0	59
Restricted ventilation of 600 cu. ft./hr. per person as recommended	2400	1·6	46

3. 1. 1. 6. *Heating System.* The heating system may be used to warm the whole room so that the occupants are comfortable wherever they sit. Alternatively (and this is more often the case with small radiant sources) the heating is used locally. Persons sitting in the direct beam of radiation from the source are comfortable, but outside the beam, conditions within the room are less comfortable. This method is the more economical of fuel, although obviously the conditions in the room are not strictly comparable in the two cases. This method of warming cannot strictly be described as space heating; rather is it "personal" warming, and it has been dealt with more fully in paragraph 3. 1. 5 below under that heading.

CALCULATION OF HEAT LOSS

3. 1. 2. The hourly heat loss through a wall or other partition of area A sq. ft. and thermal transmittance U B.Th.U./sq. ft./hr./°F. when there is a difference of temperature of T° F. between the air on the two sides of the wall or partition is:

$$h = A.U.T \quad \text{B.Th.U.}$$

The total hourly heat loss from a room or building (and therefore the hourly heat requirement) is thus:

$$H = (A_1 . U_1 . T_1 + A_2 . U_2 . T_2 + \ldots\ldots + V_a . T_a \times 0{\cdot}019) \text{ B.Th.U.}$$

where A_1, A_2, etc. = Area of walls, windows, floor, etc. (sq. ft.).

U_1, U_2, etc. = Thermal transmittance appropriate to the areas A_1, A_2, etc. (B.Th.U./sq. ft./hr./°F).

T_1, T_2, etc. = Difference of air temperature on the two sides of A_1, A_2, etc. (°F.).

V_a = Volume of ventilating air (cu. ft. per hour).

T_a = Difference of temperature between inside and outside (°F.).

This enables the heat loss to be calculated for any period of the year. In order to calculate the average seasonal heat requirement for continuous heating to a constant temperature, the following expression is used:

$$\text{Seasonal heat requirement} = (A_1 . U_1 . D_1 + A_2 . U_2 . D_2 + \ldots + V_a . D_a . \times 0{\cdot}019) \times 24 \text{ B.Th.U.}$$

where A, U, V_a have the same meanings as before and D_1, D_2 . . . D_a are the number of degree-days using the base [1] appropriate to the heating conditions to be maintained in the room. (In the case of a partition between two heated rooms, the value of D is the difference between the degree-days appropriate for the heating in each room.) This method of calculation, based on difference of air temperature, has generally been accepted as a reasonable basis for use with a heating system wholly or mainly convective (*e.g.* hot-water radiators). Some doubt has, however, been expressed as to the validity of the air temperature difference as a direct factor in determining the heat loss when radiant heating is used (*e.g.* open fires). Dufton has suggested that the equivalent temperature would form a more reasonable basis for the calculation whatever the type of heating, but this has not yet come to be generally accepted in this country. For the purpose of this Report, the heat losses to the outside have been calculated from the "air-to-air" coefficient and the difference between the air temperature outside and the equivalent temperature inside the heated room; and losses through partition walls from the difference of equivalent temperature on each side of the wall. The expression given above will still hold, provided the number of degree-days is obtained from the equivalent temperature, and not the air temperature.

This method of calculating heat losses cannot be used to compute fuel requirements when purely local or "personal" warming is employed. It must be recog-

[1] The base of the degree-day is taken as 5° F. below the temperature to which the room is normally heated (paragraph 3. 1. 1. 1).

nized that this method of calculating heat losses does not take into account either the humidity of the air or the question of whether the outdoor temperature is rising or falling. These factors will have some effect on the quantity of heat required and on the temperature at which background heating should be discontinued.

HEAT LOSSES FROM TYPICAL SMALL HOUSE AND FLAT

3. 1. 3. In order to note the relative importance of the various factors influencing the heat requirements of dwellings,[1] analyses have been made of the heat losses from a typical small house and from typical working-class flats according to whether they are on the ground floor, on an intermediate floor, or top floor. The top floor flat has been worked out for three different roof constructions. The calculations have been made for a particular temperature cycle (set out below), but the comparison will still be reasonably good if other cycles are assumed. (The amounts of heat lost through the various external surfaces of the dwelling will remain in constant ratio, although the relative amounts transmitted from one room to another may change with the temperature conditions.)

The house and flat are fairly typical of those erected before the war by local authorities.

Details of the buildings are as follows:

The House.

Conditions of exposure: normal suburban.

A centre house in a terrace.

Accommodation: 3 bedrooms, living room, kitchen, scullery, bath.

Floor area: 768 ft. super.

TABLE 3 (3)

HEAT TRANSMITTANCE COEFFICIENTS FOR COMPUTATION OF HEAT LOSS FROM TERRACE HOUSE OF TYPICAL PLAN

	CONSTRUCTION	THERMAL TRANSMITTANCE (B.Th.U. per sq. ft. per hr. per ° F.)
External Walls	9-in. brick, plastered one side	0·43
,,	11-in. cavity brickwork, ventilated, plastered one side	0·34
,,	—	0·15 (living room), 0·20 (other rooms) [2]
Partition Wall	4½-in. brick, plastered both sides	0·46
Ground Floor	Ventilated board and joist floor	0·35
	Wood floor on concrete on ground	0·15 [2]
First Floor	Boards and joists, ½-in. fibreboard ceiling	0·21
Roof	Tiles on battens, plaster ceiling	0·56
,,	Tiles on battens, boarded and felted, ½-in. fibreboard ceiling	0·22
,,	—	0·20 [2]
Window	Single glazing	1·00
Door	1-in. wood	0·50

[1] Although this degree-day method can be used to determine the relative importance of the various factors relating to the heat requirements of the building, it has limitations in regard to the determination of the heat to be delivered by an appliance to meet those requirements.

[2] Recommended maximum value, see Chapter 4.

Since the house is assumed to be a centre house in a terrace, there will be no heat loss through the party walls, both living rooms being equally heated.

The Flat.

Conditions of exposure: urban (see paragraph 3. 1. 1. 2).

The value of the heat transmittance coefficients used will depend upon the height of the particular flat above the ground, the exposure being more severe at higher levels. Normal exposure has been assumed.

Accommodation: 3 bedrooms, living room, kitchen, scullery, bath.

Floor area: 768 ft. super.

TABLE 3 (4)

HEAT TRANSMITTANCE COEFFICIENTS FOR COMPUTATION OF HEAT LOSS FROM FLATS OF TYPICAL PLAN

	CONSTRUCTION	THERMAL TRANSMITTANCE (B.Th.U. per sq. ft. per hr. per ° F.)
External Walls	13½-in. brick, plastered internally	0·35
Partition Walls	4½-in. brick, plastered both sides	0·46
External Door	Wood	0·50
Internal Door	Wood	0·41
Staircase Wall	9-in. brick, plastered room side	0·36
Windows	Normal, single glazing	1·00
Ground Floor	Concrete slab on ground	0·20
Roof, Case (i)	6-in. concrete slab, covered asphalt	0·57
Case (ii)	5-in. concrete slab, 2-in. lightweight concrete screed, covered asphalt	0·37
Case (iii)	As Case (ii) but with ½-in. wallboard on battens	0·20

The warmth conditions assumed for the various rooms are approximately those already laid down as desirable (paragraph 2. 1. 9), and the ventilation rates are assumed to be the minimum recommended (paragraph 2. 2. 8) and not the very large rates which can be induced by uncontrolled open fires. The heat losses have been calculated for intermittent heating of the rooms during periods of occupancy, together with a continuous "background" temperature of 50° F. throughout the 24 hours. The cycle assumed is as follows:

Living room: Topping-up to 65° F. for 9½ hr. in 3 periods and 55° F. for 6 hr. in 2 periods.
Kitchen: ,, ,, 60° F. for 12 hr.
Bedrooms: ,, ,, 55° F. for 2 hr. in 2 periods.
Hall: ,, ,, 55° F. for 15½ hr.
Bathroom: ,, ,, 60° F. for ½ hr. in 1 period.[1]

3. 1. 3. 1. The analyses of the heat losses from the house and from the flats for the south of England are given in detail in Tables 3 (6) and 3 (7) for heating to this temperature cycle. The annual totals for the background heating and for topping-up are as follows (the figures are in millions of B.Th.U.):

[1] Note however that in the calculations in Chapter 7, the bathroom is assumed to be warmed by a heated towel rail in continuous operation, and provision for topping-up would not then be required.

TABLE 3 (5)

TOTAL HEAT LOSSES PER ANNUM FROM A TYPICAL TERRACE HOUSE AND FLAT IN SOUTH OF ENGLAND

	BACKGROUND HEATING	TOPPING-UP	TOTAL
House with poor insulation	9·42	15·38	24·80
House with medium insulation	6·19	12·66	18·85
House with recommended insulation	4·94	11·32	16·26
Intermediate-floor flat	4·66	8·38	13·04
Ground-floor flat	6·84	10·19	17·03
Top-floor flat with poorly insulated roof *	10·82	13·52	24·34
Top-floor flat with well insulated roof †	6·84	10·19	17·03

* As Case (i), Table 3 (4). † As Case (iii), Table 3 (4).

The Tables show that for the conditions assumed, background heating to the moderate temperature suggested forms only about one-third of the total annual heat losses from the house or flat. The use of insulation may reduce the losses by as much as one-third in some cases.

For the room-heating conditions selected, the heat loss from the living room is greater than that from the rest of the house or flat, being for the cases considered about 50 per cent of the total heat loss. Very little heat is needed to keep each of the other rooms up to the moderate standard of heating recommended. Averaged over the 24 hours, there is a heat gain in some rooms from the heated living room. It varies, however, at different times of the day, and does not necessarily occur at the times when heat is needed in the other rooms. In consequence, it is necessary to provide supplementary heating to maintain the recommended conditions. An "economy standard," with reduced background heating, might represent an acceptable compromise between the heating cycle assumed and that for which many people would wish to pay (*e.g.* in some cases, people may not wish to maintain the living room at 65° F. for 9½ hours a day in addition to the kitchen maintained at 60° F. during the daytime. Others may not wish to warm the bathroom, hall, or bedrooms to the extent which has been assumed).

As the heat loss from a house in the north of England is about 25 per cent greater than from a house in the south, the efficiency of appliances and heat insulation of the building are even more important in the north than they are in the south.

It will be seen that the intermediate-floor flat requires about 25 per cent less heat than the moderately insulated house giving very similar accommodation. The heat losses from the ground-floor flat are slightly less than from the house, but only with a well-insulated roof can the losses from a top-floor flat be kept down to those of a typical house with a pitched roof.

If the houses are in semi-detached pairs, either the pairs will have the living rooms adjacent or the kitchens adjacent. The increased heat loss for the semi-detached house over that of the terrace house is least when the living rooms are on the party wall. The importance of this point turns on the questions of sound insulation and of plumbing. It has been suggested that the nuisance of sound transmission from living room to living room in semi-detached pairs could be much reduced by putting the kitchens on the party wall. The additional heat loss from the living room, however, is quite a serious item, and it would seem preferable to keep the living rooms on the party wall, and rely for sound insulation on a party wall in cavity construction, which experiments have shown to give very good insulation. The small extra cost involved would be offset by the fuel saving in a few heating seasons.

Table 3 (6a)

Heat Loss in Millions of B.Th.U. per Annum from a Terrace House of Typical Plan in South of England (Poor Insulation)

	Thermal Transmittance U. B.Th.U./sq. ft./hr./°F.	Living Room Area sq. ft.	Living Room Heat Loss [1]	Kitchen Area sq. ft.	Kitchen Heat Loss	Hall Area sq. ft.	Hall Heat Loss	Bathroom Area sq. ft.	Bathroom Heat Loss	Bedroom 1 Area sq. ft.	Bedroom 1 Heat Loss	Bedroom 2 Area sq. ft.	Bedroom 2 Heat Loss	Bedroom 3 Area sq. ft.	Bedroom 3 Heat Loss	Total Heat Loss
(i) Background heating of whole house to a temperature of 50° F. throughout the 24 hours																
External Walls	0·43	155	0·96	72	0·44	30	0·19	43	0·27	144	0·89	79	0·49	54	0·34	3·58
Glass in Windows	1·00	41	0·59	9	0·13	—	—	8	0·12	26	0·37	13	0·19	13	0·19	1·59
Ground Floor	0·35	184	0·93	96	0·48	58	0·29	37	0·19	—	—	—	—	—	—	1·89
Ceiling and Roof	0·56	—	—	—	—	—	—	—	—	161	1·30	97	0·78	67	0·54	2·62
External Door	0·50	—	—	21	0·15	21	0·15	—	—	—	—	—	—	—	—	0·30
Ventilation	—	2400 (c.f.h.)	0·66	1000 (c.f.h.)	0·27	900 (c.f.h.)	0·25	600 (c.f.h.)	0·16	1200 (c.f.h.)	0·33	600 (c.f.h.)	0·16	600 (c.f.h.)	0·16	1·99
Total heat loss			3·14		1·47		0·88		0·74		2·89		1·62		1·23	11·97
Allowance for heat gain [2]			—		—		−0·65		−0·74		−0·31		−0·50		−0·35	−2·55
Net heat loss			3·14		1·47		0·23		—		2·58		1·12		0·88	9·42
(ii) Topping-up as required (paragraph 3. 1. 3)																
External Walls	0·43	155	2·31	72	0·67	30	0·16	43	0·01	144	0·10	79	0·05	54	0·04	3·34
Glass in Windows	1·00	41	1·42	9	0·19	—	—	8	0·01	26	0·04	13	0·02	13	0·02	1·70
Partition Walls	0·46	136	1·69	136	0·82	214	−0·87	160	−1·64	—	—	—	—	—	—	+2·51 / −2·51
First Floor	0·21	184	1·15	96	0·40	58	0·11	37	−0·01	161	−0·41	97	−0·66	67	−0·46	+1·66 / −1·54
Ceiling and Roof	0·56	—	—	—	—	—	—	—	—	161	0·14	97	0·09	67	0·06	0·29
Ground Floor	0·35	184	2·24	96	0·73	58	0·25	37	0·01	—	—	—	—	—	—	3·23
External Door	0·50	—	—	21	0·23	21	0·13	—	—	—	—	—	—	—	—	0·36
Ventilation	—	2400 (c.f.h.)	1·58	1000 (c.f.h.)	0·41	900 (c.f.h.)	0·21	600 (c.f.h.)	0·01	1200 (c.f.h.)	0·04	600 (c.f.h.)	0·02	600 (c.f.h.)	0·02	2·29
Total heat losses (excluding gains from other rooms)			10·39		3·45		0·86		0·04		0·32		0·18		0·14	15·38
Total net heat loss (background heating *plus* topping-up)			13·53		4·92		1·09		0·04		2·90		1·30		1·02	24·80

[1] Heat losses are given in millions of B.Th.U. per annum.
[2] See paragraph 3. 1. 3. 1. An arbitrary maximum of 75 per cent of the heat gains during topping-up periods has been allowed.

TABLE 3 (6b)

HEAT LOSS IN MILLIONS OF B.TH.U. PER ANNUM FROM A TERRACE HOUSE OF TYPICAL PLAN IN SOUTH OF ENGLAND (MEDIUM STANDARD OF INSULATION)

	THERMAL TRANSMITTANCE U.	LIVING ROOM		KITCHEN		HALL		BATHROOM		BEDROOM 1		BEDROOM 2		BEDROOM 3		TOTAL
	B.Th.U./sq. ft./hr./°F.	Area sq. ft.	Heat Loss [1]	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Heat Loss
(i) BACKGROUND HEATING OF WHOLE HOUSE TO A TEMPERATURE OF 50° F. THROUGHOUT THE 24 HOURS																
External Walls	0·34	155	0·76	72	0·35	30	0·15	43	0·21	144	0·71	79	0·39	54	0·27	2·84
Glass in Windows	1·00	41	0·59	9	0·13	—	—	8	0·12	26	0·37	13	0·19	13	0·19	1·59
Ground Floor	0·15	184	0·40	96	0·21	58	0·13	37	0·08	—	—	—	—	—	—	0·82
Ceiling and Roof	0·22	—	—	—	—	—	—	—	—	161	0·51	97	0·31	67	0·21	1·03
External Door	0·50	—	—	21	0·15	21	0·15	—	—	—	—	—	—	—	—	0·30
Ventilation	—	2400 (c.f.h.)	0·66	1000 (c.f.h.)	0·27	900 (c.f.h.)	0·25	600 (c.f.h.)	0·16	1200 (c.f.h.)	0·33	600 (c.f.h.)	0·16	600 (c.f.h.)	0·16	1·99
Total heat loss			2·41		1·11		0·68		0·57		1·92		1·05		0·83	8·57
Allowance for heat gain [2]			—		—		−0·65		−0·57		−0·31		−0·50		−0·35	−2·38
Net heat loss			2·41		1·11		0·03		—		1·61		0·55		0·48	6·19
(ii) TOPPING-UP AS REQUIRED (PARAGRAPH 3. 1. 3)																
External Walls	0·34	155	1·83	72	0·53	30	0·13	43	0·01	144	0·08	79	0·04	54	0·03	2·65
Glass in Windows	1·00	41	1·42	9	0·19	—	—	8	0·01	26	0·04	13	0·02	13	0·02	1·70
Partition Walls	0·46	136	1·69	136	0·82	214	−0·87	160	−1·64	—	—	—	—	—	—	+2·51 −2·51
First Floor	0·21	184	1·15	96	0·40	58	0·11	37	−0·01	161	−0·41	97	−0·66	67	−0·46	+1·66 −1·54
Ceiling and Roof	0·22	—	—	—	—	—	—	—	—	161	0·05	97	0·03	67	0·02	0·10
Ground Floor	0·15	184	0·96	96	0·31	58	0·11	37	0·01	—	—	—	—	—	—	1·39
External Door	0·50	—	—	21	0·23	21	0·13	—	—	—	—	—	—	—	—	0·36
Ventilation	—	2400 (c.f.h.)	1·58	1000 (c.f.h.)	0·41	900 (c.f.h.)	0·21	600 (c.f.h.)	0·01	1200 (c.f.h.)	0·04	600 (c.f.h.)	0·02	600 (c.f.h.)	0·02	2·29
Total heat losses (excluding gains from other rooms)			8·63		2·89		0·69		0·04		0·21		0·11		0·09	12·66
Total net heat loss (background heating *plus* topping-up)			11·04		4·00		0·72		0·04		1·82		0·66		0·57	18·85

[1] Heat losses are given in millions of B.Th.U. per annum.

[2] See paragraph 3. 1. 3. 1. An arbitrary maximum of 75 per cent of the heat gains during topping-up periods has been allowed.

TABLE 3 (6c)

HEAT LOSS IN MILLIONS OF B.TH.U. PER ANNUM FROM A TERRACE HOUSE OF TYPICAL PLAN IN SOUTH OF ENGLAND (RECOMMENDED STANDARD OF INSULATION)

	THERMAL TRANSMITTANCE U.	LIVING ROOM		KITCHEN		HALL		BATHROOM		BEDROOM 1		BEDROOM 2		BEDROOM 3		TOTAL
	B.Th.U./sq. ft./hr./°F.	Area sq. ft.	Heat Loss [1]	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Heat Loss
(i) BACKGROUND HEATING OF WHOLE HOUSE TO A TEMPERATURE OF 50° F. THROUGHOUT THE 24 HOURS																
External Walls	0·15	155	0·34	—	—	—	—	—	—	—	—	—	—	—	—	1·57
	0·20	—	—	72	0·21	30	0·09	43	0·12	144	0·42	79	0·23	54	0·16	
Glass in Windows	1·00	41	0·59	9	0·13	—	—	8	0·12	26	0·37	13	0·19	13	0·19	1·59
Ground Floor	0·15	184	0·40	96	0·21	58	0·13	37	0·08	—	—	—	—	—	—	0·82
Ceiling and Roof	0·20	—	—	—	—	—	—	—	—	161	0·46	97	0·28	67	0·19	0·93
External Door	0·50	—	—	21	0·15	21	0·15	—	—	—	—	—	—	—	—	0·30
Ventilation	—	2400 (c.f.h.)	0·66	1000 (c.f.h.)	0·27	900 (c.f.h.)	0·25	600 (c.f.h.)	0·16	1200 (c.f.h.)	0·33	600 (c.f.h.)	0·16	600 (c.f.h.)	0·16	1·99
Total heat loss			1·99		0·97		0·62		0·48		1·58		0·86		0·70	7·20
Allowance for heat gain [2]			—		—		−0·62		−0·48		−0·31		−0·50		−0·35	−2·26
Net heat loss			1·99		0·97		—		—		1·27		0·36		0·35	4·94
(ii) TOPPING-UP AS REQUIRED (PARAGRAPH 3. 1. 3)																
External Walls	0·15	155	0·81	—	—	—	—	—	—	—	—	—	—	—	—	1·31
	0·20	—	—	72	0·31	30	0·08	43	0·01	144	0·05	79	0·03	54	0·02	
Glass in Windows	1·00	41	1·42	9	0·19	—	—	8	0·01	26	0·04	13	0·02	13	0·02	1·70
Partition Walls	0·46	136	1·69	136	0·82	214	−0·87	160	−1·64	—	—	—	—	—	—	+2·51 / −2·51
First Floor	0·21	184	1·15	96	0·40	58	0·11	37	−0·01	161	−0·41	97	−0·66	67	−0·46	+1·66 / −1·54
Ceiling and Roof	0·20	—	—	—	—	—	—	—	—	161	0·05	97	0·03	67	0·02	0·10
Ground Floor	0·15	184	0·96	96	0·31	58	0·11	37	0·01	—	—	—	—	—	—	1·39
External Door	0·50	—	—	21	0·23	21	0·13	—	—	—	—	—	—	—	—	0·36
Ventilation	—	2400 (c.f.h.)	1·58	1000 (c.f.h.)	0·41	900 (c.f.h.)	0·21	600 (c.f.h.)	0·01	1200 (c.f.h.)	0·04	600 (c.f.h.)	0·02	600 (c.f.h.)	0·02	2·29
Total heat losses (excluding heat gains from other rooms)			7·61		2·67		0·64		0·04		0·18		0·10		0·08	11·32
Total net heat loss (background heating *plus* topping-up)			9·60		3·64		0·64		0·04		1·45		0·46		0·43	16·26

[1] Heat losses are given in millions of B.Th.U. per annum.
[2] See paragraph 3. 1. 3. 1. An arbitrary maximum of 75 per cent of the heat gains during topping-up periods has been allowed.

TABLE 3 (7)

HEAT LOSS IN MILLIONS OF B.TH.U. PER ANNUM FROM A TYPICAL SMALL FLAT IN SOUTH OF ENGLAND (LONDON)

	THERMAL TRANSMITTANCE U.	LIVING ROOM		KITCHEN		HALL		BATHROOM		BEDROOM 1		BEDROOM 2		BEDROOM 3			TOTAL
	B.Th.U./sq. ft./hr./°F.	Area sq. ft.	Heat Loss [1]	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss	Area sq. ft.	Heat Loss		
(i) BACKGROUND HEATING OF WHOLE FLAT TO A TEMPERATURE OF 50° F. THROUGHOUT THE 24 HOURS																	
External Wall (13½ in.)	0·35	70	0·35	42	0·21	—	—	45	0·23	73	0·37	72	0·36	82	0·41	1·93	
Glass in Windows	1·00	41	0·59	17	0·25	—	—	8	0·12	26	0·37	13	0·19	13	0·19	1·71	
Ventilation	—	2400 (c.f.h.)	0·66	1000 (c.f.h.)	0·27	900 (c.f.h.)	0·25	600 (c.f.h.)	0·16	1200 (c.f.h.)	0·33	600 (c.f.h.)	0·16	600 (c.f.h.)	0·16	1·99	
External Door	0·50	21	0·15	—	—	21	0·15	—	—	—	—	—	—	—	—	0·30	Net heat loss (background heating) :—
Staircase Wall	0·36	—	—	—	—	—	—	—	—	—	—	89	0·46	—	—	0·46	
Allowance for heat gain [2]	—	—	—	—	−0·13	—	—	—	−0·29	—	−0·29	—	−0·26	—	−0·76	−1·73	Intermediate Floor Flat 4·66
Ground Floor	0·20	160	0·46	75	0·22	100	0·29	76	0·22	120	0·35	110	0·32	110	0·32	2·18	Ground Floor Flat 6·84
Roof (i)	0·57	160	1·31	75	0·62	100	0·82	76	0·62	120	0·99	110	0·90	110	0·90	6·16	Top Floor Flat (i) 10·82
(ii)	0·37	160	0·85	75	0·40	100	0·53	76	0·41	120	0·64	110	0·59	110	0·59	4·01	(ii) 8·67
(iii)	0·20	160	0·46	75	0·22	100	0·29	76	0·22	120	0·35	110	0·32	110	0·32	2·18	(iii) 6·84
(ii) TOPPING-UP AS REQUIRED (PARAGRAPH 3. 1. 3)																	
External Wall	0·35	70	0·85	42	0·32	—	—	45	0·01	73	0·04	72	0·04	82	0·05	1·31	
Glass in Windows	1·00	41	1·42	17	0·37	—	—	8	0·01	26	0·04	13	0·02	13	0·02	1·88	
Partition Walls	0·46	188	1·45	216	0·66	456	0·07	238	−0·38	188	−0·38	178	−0·34	157	−1·08	+2·18 / −2·18	
Staircase Wall	0·36	—	—	—	—	—	—	—	—	—	—	89	0·05	—	—	0·05	
External Door	0·50	21	0·37	—	—	21	0·13	—	—	—	—	—	—	—	—	0·50	
Internal Door	0·41	31½	0·17	31½	−0·17	—	—	—	—	—	—	—	—	—	—	+0·17 / −0·17	Heat loss (topping-up) :—
Ventilation	—	2400 (c.f.h.)	1·58	1000 (c.f.h.)	0·41	900 (c.f.h.)	0·21	600 (c.f.h.)	0·01	1200 (c.f.h.)	0·04	600 (c.f.h.)	0·02	600 (c.f.h.)	0·02	2·29	Intermediate Floor Flat 8·38
Ground Floor	0·20	160	1·11	75	0·32	100	0·25	76	0·01	120	0·04	110	0·04	110	0·04	1·81	Ground Floor Flat 10·19
Roof (i)	0·57	160	3·16	75	0·92	100	0·71	76	0·04	120	0·11	110	0·10	110	0·10	5·14	Top Floor Flat (i) 13·52
(ii)	0·37	160	2·06	75	0·60	100	0·46	76	0·03	120	0·07	110	0·07	110	0·07	3·36	(ii) 11·74
(iii)	0·20	160	1·11	75	0·32	100	0·25	76	0·01	120	0·04	110	0·04	110	0·04	1·81	(iii) 10·19
Total net heat loss (background heating *plus* topping-up)																	Intermediate Floor Flat 13·04 Ground Floor Flat 17·03 Top Floor Flat (i) 24·34 (ii) 20·41 (iii) 17·03

[1] Heat losses are given in millions of B.Th.U. per annum.
[2] See paragraph 3. 1. 3. 1. An arbitrary maximum of 75 per cent of the heat gains during topping-up periods has been allowed.

3. 1. 4. INTERMITTENT HEATING

3. 1. 4. 1. It is of course recognized that in practice rooms are occupied intermittently and not continuously. A few points connected with the problem of intermittent heating may be noted here without entering into a detailed consideration. The amount of heat required cannot be calculated so readily as for the case of continuous heating, since the air and walls are no longer at constant temperatures. The rate at which the surfaces warm up must therefore be considered in addition to the other factors previously mentioned. The time-lag before the heating appliance gives its full output will also affect the problem. Further, the fuel requirement (though not the heat requirement) is governed by the ease with which the output of the appliance can be regulated, and this factor is more important with intermittent heating than with continuous heating. When a source of heat is turned on, the air temperature and the temperature of the surfaces of the room do not immediately rise to the values necessary for comfort, but rise slowly over a period of some hours. This pre-heating period, as it may be called, varies according to the heat output of the appliance, being shorter the greater the output; and it also depends very largely on the nature of the internal surfaces of the walls, etc. If the appliance has an output just sufficient to balance the "steady state" losses, the temperatures would never quite attain the values required, and it would take several hours to approach them sufficiently closely for practical purposes. If the appliance can be made to give a greater output during the pre-heating period, this time may be much shortened. In general, the amount of fuel required decreases as the pre-heating period is reduced, because the length of time during which losses may occur is also reduced.

The actual amount of pre-heating necessary depends on the previous "history" of the room, *i.e.* the number of days per week and the length of time each day during which it is warmed to a comfortable temperature, and also on whether the room is slightly warmed at night and other unoccupied periods. The more nearly continuous the heating, the less is the pre-heating required.

Conditions of warmth assumed in this Report may be reached in about $1\frac{1}{2}$ to 2 hours in an ordinary room warmed daily from cold by radiant sources, the hourly heat input during this period being about 2 to 3 times the hourly input required for the maintenance of the steady state.

The total heat input necessary to reach and maintain comfortably warm conditions when the room is heated intermittently may then be estimated. The approximate relative heat requirements for different periods of occupation are given in Table 3 (8) expressed as percentages of the requirement for continuous heating over the 24-hour period.

TABLE 3 (8)

TOTAL HEAT INPUT REQUIREMENTS FOR INTERMITTENT HEATING

DAILY PERIOD OF OCCUPATION (HOURS)	TOTAL HEAT INPUT REQUIRED (AS PERCENTAGE OF THAT FOR CONTINUOUS HEATING OVER 24 HOURS)
2	25–35
5	35–45
10	60–75
15	75–90

In view of the considerations outlined above, these figures can only serve as a rough guide.

3. 1. 4. 2. The addition to the walls of a thin layer of an insulating material having a low thermal capacity enables the inner surface of the walls of a room to warm up more quickly, and a comfortable condition is obtained much sooner than in a room with a normal plaster finish.

By "low thermal capacity" is implied the characteristic of a material requiring little heat to warm it up. Materials such as wood panelling, plywood, fibreboards, cork tile, etc., are materials of low thermal capacity, while materials such as brickwork, concrete, plaster, etc., are of relatively high thermal capacity.

In a case investigated experimentally, the pre-heating period for a dining room was reduced from 1½ hours to ½ hour by the use of oak panelling. The time required for pre-heating is considerably reduced whatever method of heating is used, and the shortening of this pre-heating period represents a saving in the fuel requirement.

The effect of such a low thermal capacity lining may be seen from Table 3 (9), in which the total heat input necessary to reach and maintain comfortably warm conditions has been calculated for a lined room on the basis explained in paragraph 3. 1. 4 above.

TABLE 3 (9)

EFFECT OF LOW THERMAL CAPACITY LININGS

DAILY PERIOD OF OCCUPATION (HOURS)	TOTAL HEAT INPUT REQUIRED (AS PERCENTAGE OF THAT NEEDED FOR CONTINUOUS HEATING OVER 24 HOURS)	
	Unlined Room	Lined Room
2	25–35	12–25
5	35–45	25–35
10	60–75	50–65
15	75–90	65–80

The *proportional* saving is clearly greatest when the period of occupation is short; but in all cases of intermittent heating (as in most small houses in Britain) the use of such linings should result in a saving of fuel.

It should be mentioned that the presence of furniture also reduces the pre-heating period, and for actual conditions in practice the savings may be somewhat less than those shown by Table 3 (9). On the other hand, some additional saving may result from the fact that many low thermal capacity linings have some value as thermal insulation.

In this connection a particular furnished room was found to require about 20 per cent less fuel to heat it and keep it warm than did the same room unfurnished. It is not possible to say in general what is the effect of furniture, although it is possible that it accounts partly for the base temperature in degree-day calculations being 5° F. lower than the desired internal temperature. No specific allowance for furniture is made in calculations in the present Report.

An important point is that these linings can easily be fixed in existing dwellings, and this opens up the possibility of reduced fuel consumption and of economy to the individual in existing houses as well as in new housing.

The need for warmth in a room for occasional use arises even in the small house. It is desirable that provision should always be made for heating a room additional to the living room for use as a study in which, if need be, the children can do their homework without the distraction of the bustle of the living room and the

wireless, etc. In the typical small house this means using one of the bedrooms, which will therefore have to be heated. The use of a low thermal capacity lining would reduce the pre-heating period and so give comfort very much sooner. As many of the materials suitable for this purpose are combustible and encourage the spread of flame, consideration should be given to the increased fire hazard and where necessary suitable surface treatment be applied.

PERSONAL WARMING

3. 1. 5. The warming effect of an open coal, gas, or electric fire is due in large part to the radiation received upon the body. The intensity of the radiation is not the same in all parts of the room, so that equal warmth is not experienced at all points. There is thus the possibility of using a radiant source for purely "personal" warming, when the equivalent temperature is raised in a restricted area of the room, no attempt being made to make the whole room comfortably warm. Further, with gas and electricity the full effect of the radiation is felt almost immediately after the source is turned on, and this is particularly important for short period use. (See paragraph 2. 1. 5. 7.)

Such a method of warming, using a low-input radiant source close to the person, is obviously unsuitable as the sole means of warming the living room in winter, although at certain times of the year it may be satisfactory. It has already been mentioned that for sedentary occupation an air temperature of at least 55° F. is required, or the radiation needed is very intense and leads to the condition of feeling cold at the back and scorched in front. A fire giving out only a small quantity of heat would require a long time to raise the air temperature of an otherwise unheated room to 55° F. If, however, the air temperature is raised by other means, the small radiant source may then be used; and indeed such a method of heating, combining high-temperature radiation with convection, appears to be favoured by many people in this country.

When the time of occupation is short (as, for instance, while dressing in the bedrooms) it is probably not important to restrict the intensity of radiation to the 40 B.Th.U./sq. ft./hr. suggested earlier as a maximum for sedentary conditions, nor to insist on an air temperature greater than 55° F. The required equivalent temperature may then be obtained in a part of the room by the use of a small radiant fire; and the size of the appliance must be judged by the intensity of radiation at a distance of, say, 4 ft. in front. A gas fire consuming 12 cu. ft. of gas per hour, or an ordinary 1-kW. electric fire, will provide a radiant intensity of approximately 40 B.Th.U. per sq. ft. per hour at a distance of 4 ft. from the appliance.[1] The precise value of the radiation will, of course, depend on the design of the fire and, in particular, whether it includes a reflector.

3. 2. THE AMOUNT OF HEAT NEEDED FOR HOT-WATER SERVICES

The requirements for hot water for domestic purposes for a family of four persons have been discussed in Chapter 2, where it was estimated that about 250 gallons per week, at the supply temperature of 140° F., would be needed.

3. 2. 1. SOLID-FUEL BOILERS

3. 2. 1. 1. In order to estimate the amount of heat normally required for heating the recommended quantities of water by means of solid-fuel boilers, it is necessary

[1] A coal fire burning 1 lb. per hour would also provide about the same intensity of radiation; but it is not very suitable for short periods of use.

to consider the layout of the system and the length of the pipes. For purposes of analysis of the heat requirements, three cases have been chosen. (These cases are intended for purposes of illustration only, and are not always the most practical layouts.)

The pipe lengths for the three cases are then as follows:

Case I. Compact hot-water supply system.

Independent boiler in scullery. Hot tank in airing cupboard in bathroom over scullery.

$1\frac{1}{4}$-in. dia. pipe flow and return, 8 ft.+8 ft. long.

$\frac{1}{2}$-in. dia. "draw-off" pipe to sink, 10 ft. long.

$\frac{3}{4}$-in. dia. ,, ,, bath and basin, 5 ft. long.

Case II. Less compact hot-water supply system.

Back boiler to living room fire. Hot tank in airing cupboard in bathroom over scullery as in Case I.

Long flow and return, 30 ft. 6 in.+30 ft. 6 in. long.

Short "draw-off" pipe to sink, 10 ft. long.

,, ,, ,, bath and basin, 5 ft. long.

Case III. Less compact hot-water supply system.

Back boiler to living room fire. Hot tank in airing cupboard in bedroom near chimney breast.

Short flow and return, 10 ft.+10 ft. long.

Long "draw-off" pipe to sink, 23 ft. long.

,, ,, ,, bath and basin, 18 ft. long.

As with the heating of rooms, the computed heat loss is a measure of the heat requirements, and the heat losses for the three cases postulated above are given in Table 3 (10) following. The tank and flow and return pipes are assumed to be always at the high temperature, and the heat losses are based on this assumption and are computed from data given by the Institution of Heating and Ventilating Engineers. The computed heat loss from the draw-off pipes is based on the assumption that the water standing in the pipes loses all its heat between the times when hot water is wanted. It is estimated for the purpose of this analysis that hot water is wanted about 25 times a day—18 times at the sink and 7 at the bath or washbasin.

The effect of insulating the system has to be taken into account and the heat losses for the three cases above are analysed with and without insulation to the tank and the flow and return pipes. The insulation is taken as a magnesia-type covering $1\frac{1}{4}$ in. thick. No insulation is provided for the draw-off pipes as its value here is limited.

It will be seen from Table 3 (10) that the use of a compact layout (Case I) results in a considerable reduction in the heat loss as compared with less compact systems. With this layout, insulation of the tank and flow and return pipes can result in a 50 per cent reduction in the net heat requirement of the system.

TABLE 3 (10)

EFFECT OF LAYOUT AND INSULATION OF THE HOT-WATER SYSTEM ON THE HEAT REQUIREMENT WITH BOILERS BURNING SOLID FUEL

Note: The Roman figures are for uninsulated hot-water systems. The Italic figures are for hot-water systems insulated with 1¼-in. magnesia-type covering.

	HEAT NEEDED FOR BOILERS BURNING SOLID FUEL (B.TH.U. PER WEEK)		
	Case I	Case II	Case III
Heat loss from 40-gal. tank in linen cupboard	340,000 *95,000*	340,000 *95,000*	340,000 *95,000*
Heat loss from flow and return pipes	200,000 *44,000*	770,000 *170,000*	250,000 *55,000*
Heat loss from standing water in draw-off pipes	22,000 *22,000*	22,000 *22,000*	58,000 *58,000*
Heat required for warming water actually used	225,000 *225,000*	225,000 *225,000*	225,000 *225,000*
Total heat input needed (B.Th.U.) uninsulated Total heat input needed (B.Th.U.) insulated	787,000 *386,000*	1,357,000 *512,000*	873,000 *433,000*

3. 2. 1. 2. *Circulating Pipes.* The effect of the long flow and return pipes is very marked. The heat loss from them, in Case II, when uninsulated, is considerably more than the heat needed to warm the water actually used. If the boiler is to be situated more than 12 ft. from the storage tank, insulation of the flow and return pipes is essential. Even with insulation the heat loss from the long flow and return pipes is nearly as much as the heat needed to warm the water actually used. It might be argued that the heat losses from the pipes would add usefully to the heating of the room in which they are installed, but this may lead to discomfort in summer.

3. 2. 1. 3. *Draw-off Pipes.* Long runs of draw-off pipe are not so wasteful of heat as long flow and return pipes between tanks and boilers; though there may be slight convection currents in the pipes which allow some heat to be wasted, and also the metal of the pipe walls has to be heated up before the water runs hot at the taps. The chief loss is the heat contained in the water left standing in the pipe after hot water has been drawn. Consequently, it is desirable that the lengths of draw-off pipes also should be kept to a minimum. A badly designed system with long runs of pipe, as in Case III above, may waste about 15 per cent of the total heat supplied to the system. It is obviously desirable to keep the diameter of draw-off pipe as small as is consistent with good service. ½-in. diameter is suggested for pipes to the sink and washbasin, but ¾ in. will be necessary for the bath.

3. 2. 1. 4. *Storage Tank.* A storage tank of 25-gallons capacity, such as is commonly used, is too small for a family of four, as it is often difficult to draw off two hot baths in quick succession. This difficulty is increased where the design of the tank and cold water inlet is such as to allow undue mixing of the cold water and the hot water remaining in the tank. It is considered that a storage tank of not less than 35- to 40-gallons capacity should be used and the cold water fed to the bottom of the tank, with suitable means provided where necessary for preventing undue mixing, such as by a deflecting elbow or tee-piece. To segregate

the hot water as far as possible, it is suggested that the height of the tank should be about twice the maximum horizontal dimension.

Where the maximum rate of heat input is low, and a sufficiently low minimum rate of burning can also be assured, the insulation of the storage tank and flow and return pipes should be increased. Where such low rates of burning cannot be assured, some heat leak should be provided, such as, for example, a towel rail.

Tanks should be fixed so that there is a clear space of three inches on all sides and on top, so as to permit insulation to be applied.

GAS AND ELECTRIC WATER HEATERS

3. 2. 2. Other types of domestic water heaters which need to be considered are electric and gas storage heaters and instantaneous gas heaters. The storage heaters are almost invariably insulated and do not have flow and return pipes. The amounts of heat required for gas and electric storage heaters and gas instantaneous heaters are summarized in Table 3 (11). With single-point heaters there are no losses due to standing water in draw-off pipes. If the heaters are of the instantaneous type, however, there may be losses when usage is infrequent due to water left in the appliance. Such losses are small if the appliance is suited to the duty required of it. The heat in the gas for a pilot light must also be included where necessary.

TABLE 3 (11)

THE HEAT REQUIRED FOR HOT-WATER SERVICES USING GAS OR ELECTRIC STORAGE HEATERS AND GAS INSTANTANEOUS HEATERS

	HEAT NEEDED (B.TH.U. PER WEEK)		
	STORAGE HEATERS		INSTANTANEOUS HEATERS (MULTI-POINT)
	Uninsulated	Insulated	
Heat loss from 40-gallon tank	340,000	40,000	—
Heat loss from standing water in draw-off pipe	22,000	22,000	22,000
Heat required for warming water actually used	225,000	225,000	225,000
Total heat input needed	587,000	287,000	247,000

3. 3. HEAT REQUIREMENTS FOR COOKING

There are wide differences in the amount of cooking done by various families, and the amount of heat required varies according to the process used, *e.g.* roasting, boiling, baking, or grilling, and is dependent upon the degree of care exercised by the cook to avoid waste of heat or inefficient use of the appliance, *e.g.* baking a small cake in a large oven. In view of these variations, it is impossible to state a definite figure for heat requirements, but recorded fuel consumptions indicate that the amount of heat absorbed under the utensils and in the oven is 50,000 to 150,000 B.Th.U. per week for a family of four persons.

3. 4. TOTAL ANNUAL HEAT REQUIREMENT FOR MAIN HEATING SERVICES

In this chapter a typical 3-bedroom terrace house (768 sq. ft. floor area) of average pre-war construction occupied by a family of four persons has been

considered. The total annual amount of useful heat theoretically necessary to heat the house to the standards suggested (paragraph 3. 1. 3) and to provide the recommended quantity of hot water with an insulated system, is of the following order:

19–25 million B.Th.U. for space heating (Table 3 (6)).
13–20 million B.Th.U. for water heating (Tables 3 (10) and (11)).

32–45 million B.Th.U. Total.

In addition, from 3 to 8 million B.Th.U. per annum are absorbed in the oven and under the utensils, bringing the total to 35–53 million B.Th.U. (350–530 therms) per annum.

In practice the heat input must exceed this figure, owing to the inability of the appliances to meet the heat requirements exactly and at all times.

CHAPTER 4

THE INSULATION OF DWELLINGS

4. 1. IMPORTANCE OF INSULATION

The coal consumed annually in the heating of dwellings and small commercial premises in Great Britain is approximately 63 million tons, and its value would equal the capital cost of 200,000 to 300,000 houses. The utmost importance should therefore be attached to the conservation of heat in the building of houses.

Improvements in the insulation of buildings will in general reduce both the fuel bill of the occupant, and the amount of coal which has to be mined. A balance must be arrived at as to the expenditure on insulation, additional to the normal cost of the building, which can justifiably be incurred on account of the substantial saving in the heating cost. No absolute criterion can be laid down, for the saving in cost of heating depends upon fuel prices and on the efficiency with which the fuel is used. The higher the thermal efficiency and the less expensive the fuel, the less will be the saving attainable by means of insulation.

4. 2. THE JUSTIFIABLE EXPENDITURE ON INSULATION

Probably the simplest basis is to examine a typical small house by way of example. The total annual heat loss from a house of normal pre-war construction (11-in. walls, timber floor and pitched roof) is about 24×10^6 B.Th.U. If the average expenditure on room heating is taken to be £10 per annum (and it is unlikely to be less than this) the cost of a million B.Th.U. lost from the dwelling is about 8*s*. 4*d*.

EXTERNAL WALLS

4. 2. 1. With a pre-war normal walling system consisting of 11-in. cavity brickwork plastered internally, the annual heat loss for all the external walls is 5·5 million B.Th.U. This represents a heating cost of 5·5 × 8*s*. 4*d*., or £2. 6*s*. 0*d*. per annum. In the example considered this loss occurs through an area of 577 sq. ft., and therefore approximately one pennyworth of heat is lost through every sq. ft. of external wall per year.

If the heated living room only is considered, however, the loss is more important

because the room is heated to a higher temperature. The annual heat loss through the external walls of the living room is 2·59 million B.Th.U., representing a heating cost of say £1. 1*s*. 6*d*. through an area of only 155 sq. ft. This represents over $1\frac{1}{2}$*d*. worth of heat per sq. ft. per annum.

Taking compound interest at $3\frac{1}{2}$ per cent over a period of 40 years, it can be assumed that every additional 1*s*. in the initial cost of a part of a building increases the amortization charge by about $\frac{1}{2}$*d*. per annum. Applying this directly to the heating costs derived above, it will be seen that one could justify an additional initial cost of external wall construction for the whole house of 1*s*. per sq. ft. if the heat losses could be halved (*i.e.* reduce U from 0·34 to 0·17) or 1*s*. 6*d*. per sq. ft. for halving the heat losses through the walls of the living room only. Actually these sums are large; and it might be difficult to persuade the occupants of the houses that the additional rent represented good value to them: it might be safer to allow an increase in initial cost equivalent to half the saving in heating cost.

The savings in heat losses over the losses through the normal 11-in. cavity wall are shown in the following Table for a variety of methods of construction, together with the justifiable increase in initial cost per sq. ft.

TABLE 4 (1)

INSULATION OF EXTERNAL WALLS

	U	SAVING % OF HEAT LOST THROUGH WALLS	ALLOWABLE INCREASE IN INITIAL COST PER SQ. FT. OF WALL (BASED ON HALF THE SAVING IN HEATING COSTS)	
			For whole house	For living room only
11-in. cavity wall brickwork (ventilated), plastered inside	·34	—	—	—
11-in. cavity wall brickwork (unventilated): 1-in. fibreboard on battens, or, 2-in. wood-wool slabs	·15	56	6*d*.	9*d*.
$9\frac{1}{2}$-in. cavity wall (unventilated): $4\frac{1}{2}$-in. brickwork, 2-in. cavity, 3-in. foamed slag concrete or insulating plaster block, plastered inside	·24	29	3*d*.	5*d*.
$\frac{1}{4}$-in. asbestos cement, 4-in. cavity, 3-in. foamed slag concrete or insulating plaster block	·27	20	$2\frac{1}{2}$*d*.	4*d*.
$\frac{1}{4}$-in. asbestos cement, 4-in. cavity, 2-in. wood-wool slab, plastered inside	·17	50	6*d*.	9*d*.

GROUND FLOOR

4. 2. 2. A pre-war ground floor construction was 1-in. (nominal) tongued and grooved flooring on timber joists with a well ventilated air space underneath. This was often furnished by the tenant with linoleum for living room, hall, and parlour. The kitchen might be the same or it might have a tiled or concrete floor finish on the solid.

The annual heat loss for the whole floor area of 375 sq. ft. would be 5·1 million B.Th.U., equivalent to an annual heating cost of about 1·3*d.* per sq. ft.

Assuming, as for the walls, that a reduction in heating cost justifies an increase in initial cost equivalent to half the value of the reduction, it will be seen that a 50 per cent reduction in heat loss from the normal ventilated wood floor justifies an increase in initial floor cost of 8*d.* per sq. ft.

In this case the heat loss from the warmed living room is much more important than that from the kitchen, bathroom, and hall, so that here again a greater increase in the cost of insulating the living room floor only is justified.

The insulation of the floor can be improved in various ways, but it has to be recognized that the necessary ventilation under a board and joist floor is the main source of heat loss. Consequently, it is probably easier to improve the insulation by using a floor finish on the solid than to pile up insulation on the ventilated floor.

Some comparative data are given in Table 4 (2) below:

TABLE 4 (2)

INSULATION OF GROUND FLOOR

	U	SAVING % OF HEAT LOST THROUGH GROUND FLOOR	ALLOWABLE INCREASE IN INITIAL COST PER SQ. FT. OF FLOOR (BASED ON HALF THE SAVING IN HEATING COSTS)	
			For whole house	For living room only
1-in. (nominal) tongued and grooved boarding on timber joists, ventilated under, covered with linoleum	0·35	—	—	—
1-in. (nominal) wood block on concrete on ground	0·15	57	9*d.*	1/-

In this case the advantage of the insulated solid floor is very great. Actually the solid floor is not likely to be more expensive than the ventilated floor, and very often it will be cheaper.

ROOF

4. 2. 3. The normal pre-war construction was slates or tiles on battens (with or without boarding and a thin felt), rafters, ceiling joists, and plasterboard or lath and plaster.

Without boarding and felt, the heat loss from the roof of the house considered would be 2·9 million B.Th.U. per annum, equivalent to a heating cost of 0·9*d.* per sq. ft. of ceiling.

On the same basis as was taken for walls and ground floor, a saving of 50 per cent in the heat loss by improved insulation would in this case justify an increase in initial cost of roof construction of 6*d.* per sq. ft., allowing only half the value of the saving in heating cost.

In the case of a top-floor flat, the warmed living room as well as the bedrooms loses heat directly through the roof, and the savings due to insulation are, therefore, greater. A reduction of 30 per cent in the heat loss from the normal roof would justify an increased initial cost of 6*d.* per sq. ft.

Some comparative data are given in Table 4 (3) on the following page.

TABLE 4 (3)

INSULATION OF ROOFS

	U	SAVING % OF HEAT LOST THROUGH ROOF AND FIRST FLOOR CEILING	ALLOWABLE INCREASE IN INITIAL COST PER SQ. FT. OF ROOF AND CEILING (BASED ON HALF THE SAVING IN HEATING COSTS)
Tiles, battens, plaster or plasterboard ceiling	0·56	—	—
Tiles, battens, boarding and felt, plaster or plasterboard ceiling	0·30	47	6*d.*
Tiles, battens, boarding and felt, ½-in. fibreboard above ceiling joists, plaster or plasterboard ceiling	0·18	68	8*d.*
Tiles on battens, felted; boarding above ceiling joists, fibreboard ceiling	0·18	68	8*d.*
Tiles on battens, felted, ½-in. fibreboard and ½-in. eelgrass quilt above joists, plaster or plasterboard ceiling	0·14	75	9*d.*
Asphalt on 6-in. concrete, plastered soffit	0·52	—	—
Asphalt on 6-in. concrete, 2-in. lightweight concrete screed, plastered soffit	0·34	35	6*d.*
Do. but with fibreboard on battens to soffit	0·20	62	1/-

There is again ample justification for a standard of insulation higher than that which has often been used in the past. There is the further advantage of a cooler house in summer.

DOUBLE GLAZING

4. 2. 4. A similar analysis of the savings resulting from the use of double glazing or double windows shows that the heat loss through the windows would be reduced by half, *i.e.* from 3·29 to 1·65 million B.Th.U. per annum for the whole house and from 2·01 to 1 million B.Th.U. per annum for the living room only; and an increased initial cost of 2*s.* 6*d.* per sq. ft. for the living room windows, or of 1*s.* 6*d.* per sq. ft. for all the windows of the house, could be justified. The savings would be somewhat greater in the colder districts, and here double glazing would be particularly valuable.

CONTROL OF HEATING APPLIANCES

4. 2. 5. It must be remembered that the full benefit of thermal insulation cannot be realized unless the appliances are such that there is adequate control over the heat output. This is probably the case with oil, gas, electricity, and large central heating plant (the theoretical saving having been very nearly obtained in tests done in America), but it is otherwise with most domestic solid-fuel appliances as at present designed. With these appliances there is a minimum rate of combustion which must be maintained if the fire is to remain alight. Although in winter this is not usually sufficient to meet the demand, it may be so in spring or autumn. Any reduction of the heat loss from the house resulting from the use of insulation does not then lead to an equivalent reduction in the fuel consumption.

4. 3. SUGGESTED MAXIMUM VALUES OF THERMAL TRANSMITTANCE

To summarize, it would be an economy to require, as maxima, the following values of the heat transmittance coefficient for alternative forms of construction, where such values can generally be easily obtained; and for normal forms of construction where the heating methods installed are controllable. (See paragraph 4. 2. 5 above.) Still lower values are to be preferred when they can be obtained economically.

External walls:		
a. for any part of the house, U not to exceed	0·20	B.Th.U./sq. ft./hr./deg. F.
b. for the walls of the warmed living room, U not to exceed	0·15	,,
Ground floor, U not to exceed	0·15	,,
Roof and top-floor ceiling, U not to exceed	0·20	,,

In houses where apparatus may be installed which is not readily controllable, there may not be the same economic justification for considerable expenditure on insulation, although there will always be some saving of fuel. In such cases the following maximum values of the heat transmittance coefficient might be appropriate:

External walls of living room, U not to exceed	0·20	B.Th.U./sq. ft./hr./deg. F.
Ground floor, U not to exceed	0·15	,,
Roof and top-floor ceiling, U not to exceed	0·30	,,

4. 4. HOW BUILDING PRACTICE IS LIKELY TO BE AFFECTED BY THE HIGHER VALUES OF THERMAL INSULATION

GROUND FLOOR

4. 4. 1. Enough has been indicated in the foregoing notes to show that the problem of the ground floor of the dwelling—whether house or flat—is not a difficult one for the industry to face. Suspended floors involve large heat losses owing to their low thermal resistance and to in-leakage of air which may take place through cracks. These effects are materially increased if the ventilation of the under-floor space is excessive, and may lead to complete ineffectiveness of low-temperature radiant ceiling heating. As mentioned above the solid floor is a possible alternative to the suspended floor, and may often prove to be cheaper. A damp-proof course is necessary with solid floors.

ROOF

4. 4. 2. The roof also presents a comparatively simple problem. The logical treatment is to concentrate the insulation on the top of the ceiling joists rather than to carry it up the sloping roof. Where the pitch of the roof is steep the amount of material required is nearly halved. Tanks and pipes in the roof space would be encased. In many of the European countries with cold winters this is the normal practice. The felt immediately under the slates or tiles is, however, very valuable; not only does it deal with occasional rain or snow leakage through

an inefficient roof covering, but it also stops air-infiltration and the rapid heat loss this would set up.

EXTERNAL WALLS

4. 4. 3. The external walls are a more difficult problem with the normal pre-war brick-built house. There are three elementary functions which the wall has to fulfil. It must sustain the load of first floor and roof and provide stability against wind and any other lateral forces; it must exclude rain, wind, and snow; and it must provide heat insulation to enable the house to be kept warm in winter.

The normal brick wall, whether solid or cavity, has an enormous reserve of strength and stability for domestic loading. This reserve is so great that it can hardly be claimed that materials are used efficiently from this point of view. As regards rain, wind, and snow exclusion, the device of the cavity construction has overcome what was a very serious problem in brick walls; the cavity wall can probably be regarded as the normal, and is a quite efficient structure from the point of view of keeping the weather out.

The foregoing notes in this section show that, judged by the above standards, the cavity brick wall can at best be ranked as indifferent from the point of view of heat insulation. But the brick wall has a number of outstanding advantages from other angles. It is the kind of wall which the public expects to find in a house, and if well built, and well proportioned with well chosen materials, it is very satisfactory to look at and to live with. It is extremely durable and, with a reasonably good brick and modern mortar, maintenance over a period of a century should be virtually negligible. Finally, and perhaps the most important consideration, it has been very economical, and no alternative method of wall construction has been able to compete with it when the necessary materials and labour were plentiful. These advantages ensure that the brick-walled house will continue to play an important part in post-war housing, and the question then is how to obtain the improved standards of heat insulation now shown to be desirable.

In the examples quoted in Table 4 (1) the additional insulation was obtained by substituting an insulating-board lining for the normal plaster lining. This amply fulfils the thermal requirements but introduces serious problems in respect of bug infestation and resistance to hard wear. It is a little difficult to get the right perspective on bug infestation. The normal pre-war plastered house could become so thoroughly infested in door linings, floor boards, architraves, skirtings, picture rails, and furniture that it would be difficult to imagine any alternative lining being worse. The question then is whether the alternative linings are seriously worse from the point of view of disinfestation by fumigation. This is a question for the specialist. So far as bug infestation is concerned, the building problem turns on harbourage, and this depends on the existence of cracks and joints. It should not be forgotten that there is now available a range of adhesives which should make it possible to seal joints effectively.

As an alternative to the provision of an additional lining, it is possible to obtain the required insulation by the use of a highly insulating building block for the inner leaf of the cavity wall whilst preserving the brick outer leaf with all its advantages of appearance and durability. Actually it may be necessary to use concrete floors and roofs in post-war housing, and it would then be a practicable solution to take the bearing for the floors and roof on the brick outer leaf, which would overcome the problem of the relatively low strength of the highly insulating materials.

Where methods of construction alternative to brick are used, there are many possibilities of securing high values of insulation. Especially is this the case when the loads are carried by a light framework, as the panel fillings can then be chosen with heat insulation as a primary requirement. There is often an advantage in separating the functions in building.

4. 5. INSULATION AND THE HEATING INSTALLATION

It is important to note that the full value of the thermal insulation of a house can be realized when the house is heated by gas, electricity, or oil, or by large central heating plant. These methods are easily controllable, and the output can be adjusted to match the required input fairly closely.

The fact that, with many present-day appliances burning solid fuel, the fuel saving cannot always give the full economic return on the cost of the insulation, calls attention to the very great importance of the flexibility and controllability of the heat output of the appliance. This is a point which merits the close attention of the manufacturers of domestic solid-fuel appliances. On the other hand, full advantage could not be taken of the low minimum combustion rate of the improved appliances if the house were not sufficiently well insulated.

CHAPTER 5

THE IMPORTANCE OF AMENITIES

5. 1. AMENITIES AS FACTORS IN CHOICE OF APPLIANCES

Amenities have, in the past, seldom been deciding factors in the choice of methods of heating buildings. A real difficulty has been the lack of data by which to assess the value of an amenity in comparing one heating system with another. Yet to refuse to give due weight to amenities must delay indefinitely some of the social and environmental changes which many people believe to be overdue.

The amenities which have not been sufficiently taken into account in the past in considering the heating of buildings are the reduction of the general atmospheric pollution, the elimination of dust and fumes from the house, and the lightening of the drudgery in the home. Much has been written and spoken on the subject of atmospheric pollution, and in some localities efforts have been made to reduce the nuisance. Domestic labour can be saved by the installation of convenient appliances; but insufficient consideration has been given in the past to this question.

5. 2. ATMOSPHERIC POLLUTION

In this Chapter, pollution resulting from the heating of domestic buildings is considered. Railways and industrial establishments (other than gasworks and electricity generating stations) are outside the scope of this Report.

NATURE OF ATMOSPHERIC POLLUTION

5. 2. 1. Atmospheric pollution is defined as the presence in the air of objectionable gases, liquid droplets, and solid particles. Practically the whole of the pollution arises from the burning of coal and the fuels derived from it, only a very small part being due to waste products from industrial processes and other sources. Of the gaseous products when coal is burnt completely, only sulphur dioxide is harmful, except for very small traces of other gases. In addition, a residue of incombustible ash is left, and some of this may be emitted with the flue gases. When the combustion is incomplete, however, soot, pitch, and tar are also produced and are discharged with the flue gases. These constituents form the major part of the visible grimy pollution. They consist of fine particles which may remain suspended in the air: ash and grit particles are larger, and are quickly deposited.

SMOKE

5. 2. 2. The domestic fire burning raw coal is the main source of soot and tar pollution. The production of smoke at electricity generating stations is relatively small owing to the much more complete combustion of the coal, and the effect of the smoke on buildings, etc., is lessened by the absence of tar and by the use of high chimneys. The smoke pollution at gasworks is also relatively small. The use of coke, anthracite, gas, and electricity in the home causes little or no smoke.

ASH

5. 2. 3. The amount of ash discharged into the air depends on the velocity of the flue gases which is low for the domestic fire burning raw coal, coke, or anthracite, and higher at electricity generating stations. Ash and grit emission at the latter has, however, been greatly reduced by the installation of grit arrestors which are now made compulsory when new generating plant is installed by public electricity supply undertakings. The use of high chimneys is also effective in dispersing any remaining grit over a wide area and thus reducing its nuisance effect. The emission of ash at gasworks is negligible, and the consumption of gas and electricity produces no ash.

SULPHUR DIOXIDE

5. 2. 4. Equal weights of coal and coke evolve, on combustion, approximately equal quantities of sulphur dioxide. Anthracite contains rather less sulphur. The cleaning of coal reduces the sulphur content by the removal of pyrites, but the proportion of sulphur present in this form varies considerably. A high proportion of the coal sold in this country is cleaned.

The quantity of sulphur dioxide emitted from electricity generating stations where flue gases are not treated is about the same as from domestic fires of equal coal consumption, but the damaging effect is considerably less owing to the diffusion from the top of a tall chimney and the much smaller ground area over which the pollution occurs in any appreciable concentration. Where flue-gas washing plant is installed (as at Battersea and Fulham power stations) sulphur dioxide is almost entirely eliminated, and it is to be hoped that some such system will in time be adopted in all large power stations and industrial installations. The consumption of electricity produces no sulphur dioxide.

The quantity of sulphur dioxide emitted from gasworks is relatively small, although there are local concentrations. The sulphur dioxide produced in the combustion of gas is also small. There is a movement in the gas industry to enforce the reduction of sulphur in gas to lower levels until ultimately the concentration is negligible. (The pollution from the coke produced has been dealt with above.)

EFFECTS OF ATMOSPHERIC POLLUTION

5. 2. 5. The ill-effects of atmospheric pollution are many and various. Some of the effects are definitely injurious to plant and animal life, and to materials, but others are merely a nuisance. The more important of the ill-effects of pollution can be enumerated as follows:

a. Damage to crops and loss of yield.
b. Increase of rickets and respiratory diseases.
c. Loss of daylight and ultra-violet light.
d. Loss of visibility.
e. Deterioration of buildings and materials.
f. Extra amount of cleaning and laundry.
g. Extra labour involved.

Details are given in Appendix 4.

COST

5. 2. 6. The total cost of atmospheric pollution cannot be accurately estimated; but taking the figures for only the more tangible effects which can be approximately assessed, it has been estimated (see Appendix 4) to amount to at least £26 million per annum, or 11*s*. per head, and it would be fairly safe to say that the final cost is not less than twice this amount, or, say, 20*s*. per head per annum of which approximately half is attributable to domestic heating and half to railways and industry. If only the pollution cost payable directly by the tenant be considered, it reduces itself to the cost of chimney cleaning and to the increased cost of laundry, house cleaning, lighting, and doctors' bills.

It may be that the financial argument for the reduction of smoke and sulphur dioxide would not weigh greatly with the average man, although the aggregate cost to the nation has been shown to be quite large. The other benefits arising from a reduction of pollution are difficult to over-emphasize; and it must be remembered that the costs cited exclude many vital items of damage which cannot be assessed.

The relative contributions to atmospheric pollution of various methods of heating are discussed in Appendix 4. The cost due to the pollution for which the domestic coal fire is responsible probably amounts to about 7*s*. per head per annum. Supposing all consumption of bituminous coal in open fires were stopped, the gas and electricity stations would have to increase their output correspondingly, and in doing so would emit some further pollution. In addition, the use of coke involves emission of sulphur dioxide; but the total saving would nevertheless be very considerable, and might amount to 5*s*. per head per annum, out of the total of 10*s*. for domestic heating.

POLLUTION AS A FACTOR IN CHOICE OF APPLIANCES

5. 2. 7. The emission of smoke from domestic chimneys represents about half the visible atmospheric impurity in many towns. Of the coal-burning appliances, the types which make the greater part of the smoke are also the least efficient from the point of view of heating; and the trouble is likely to reduce itself as these appliances are superseded. Housing authorities and others who have the responsibility of selecting heating and cooking equipment should endeavour to debit the various appliances they review with the cost of the damage inflicted by pollution. Data for this are given in Appendix 4.

NATIONAL POLICY

5. 2. 8. The annual cost of damage and loss to the nation, due to the effects of atmospheric pollution on health, buildings and other materials, and crops, is very large. Any considerable reduction in pollution will probably only be obtained if a national policy is followed. Unproductive labour will be reduced and much material economy achieved. A reduction in the cost of medical services might also follow, and gloom and dirt would be dispelled.

5. 3. SAVING OF LABOUR IN THE HOME

5. 3. 1. As a result of the upheaval caused by the war, there are likely to be changes in the way of living; the younger women will have worked and lived in surroundings and conditions very different from those of the home, and may well be less tolerant of a round of drudgery than the older generation. This is admittedly a matter for speculation, but there can be no doubt that any easing of the burden of the housewife is desirable. Apart from the wider sphere of activities, a greater attention to labour saving and cleanliness of domestic appliances should encourage and assist the housewife to keep the home clean and bright.

Heating appliances, if badly chosen and designed, are responsible for a very considerable part of the labour in a house. Kindling, carrying of fuel, removal of ash, and constant attention to appliances having poor methods of control are all appreciable items of labour.

In choosing heating appliances, it is right to debit each with the amount of labour in tending it and for cleaning up the dirt to which it gives rise. Only in this way can a fair comparison be made between the various methods of heating.

It is gratifying to note that the manufacturers of solid-fuel appliances have been encouraged to give as much attention to cleanliness and labour saving as to other aspects of design. Some of the latest models are very well designed in this respect.

CHAPTER 6

THE RELATIVE EFFICIENCIES OF METHODS OF USING THE NATIONAL COAL RESOURCES FOR THE HEATING OF BUILDINGS

6. 1. EFFICIENCY OF STAGES IN PRODUCTION AND USE OF FUEL

In this Chapter an attempt is made to evaluate some of the factors affecting the efficiency of the different methods of heating buildings—particularly from the point of view of their efficiency in terms of the corresponding coal requirements. This is a somewhat complex matter. It is not sufficient merely to compare the actual efficiencies of different appliances as such, but account must be taken of the efficiency with which coal is converted into other forms of energy at gasworks or electricity stations, and of such factors as the transmission losses between these works and stations and the actual appliances in the consumer's home. Further, technical development is a continuous process, which means that present-day figures may not be true in future years (see paragraph 6. 2. 3. (h) below).

The procedure in this Chapter is to follow through the different stages from the production of the fuel, *e.g.* at the gasworks or electricity station, to its actual conversion into heat by the appliance, and to consider the efficiency of the process at each stage. The results of the analysis are set out in Table 6 (2a) for conditions of continuous heating, in Table 6 (2b) for four cases of intermittent heating, and in Table 6 (2c) for water heating. This Chapter can be regarded as a commentary on the Tables, which must be read in the light of what is said in the Chapter, and they would be misleading if considered in isolation. A number of the factors set out in the Tables are given in terms of "spreads"; in these cases greater precision would not be justified by the existing data. The various factors covered in the Tables are the following:

PRODUCTION EFFICIENCY (P)

6. 1. 1. In the case of electricity, gas, and coke, a factor—P—must be used to express the overall efficiency of the conversion of coal into gas, coke, or electricity and the distribution of these fuels to the consumer's home. This factor does not arise when raw coal is burnt direct. It has been found convenient, for this purpose, to make allowance in this factor for the average "external transmission loss" of electricity between the power station and the consumer, and certain losses in respect of gas referred to in Annex B. P is defined as the ratio of the sum of the thermal values of the products sold for use external to the power station or gas-

works to the potential heat in the coal consumed, and is expressed as a percentage. The calculations of this factor all refer to the year 1937.

i. Electricity.

In Annex A to this Chapter are set out details for the calculation of the average production efficiency of electricity power stations, and it will be seen that the average figure for the country may be taken as 21 per cent, which is scaled down to 18 per cent to allow for external transmission losses.

ii. Gas and Coke.

In the case of gas and coke, the evaluation of the production efficiency raises complex issues, because the carbonization of coal results not in a single fuel like electricity, but in four main products—gas, coke, benzol, and tar.

Two alternative calculations are made:

a. It is generally agreed that the average thermal value of these four products is some 73 per cent of the thermal value of the original coal. Under one method of expressing this issue, the production efficiency in relation to both gas and coke is expressed at 73 per cent. This is the figure marked "(a)" in Tables 6 (2a), 6 (2b), and 6 (2c). The expression of the results in this way assumes that the whole of the gas and coke produced for sale by the gasworks are absorbed into the consuming market. This assumption will normally be correct.

b. An alternative method is to claim that the primary object of the gasworks process is to produce gas and that all other products, including coke, are incidental, though inevitably produced. Under this method, all heat losses in the process are therefore debited against the gas. The production efficiency in the case of coke is then rated at 100 per cent and that of gas at 48 per cent. Alternative figures marked "(b)" for this method of calculation are included in Tables 6 (2a), 6 (2b), and 6 (2c).

Further details as to the calculations in the case of gas production are set out in Annex B to this Chapter.

Table 6 (1) below shows the amount of coal consumed in electricity stations and gasworks in 1937, together with the output of the main and by-products. The production efficiency of each process is given.

TABLE 6 (1)

PRE-WAR EFFICIENCY OF ELECTRICITY GENERATION AND OF THE GASWORKS PROCESS

	COAL USED	SALEABLE PRODUCTS	PRODUCTION EFFICIENCY
Electricity generation (authorized undertakings)	14·0 million tons	18,300 mill. kWh.	18 per cent [1]
Gasworks (authorized undertakings)	18·65 million tons	288,400 million cu. ft. gas 8·18 million tons coke 236·8 million gallons tar	73 per cent (64 per cent excluding tar) [2]

[1] 77 per cent of total output at 20 per cent efficiency.

[2] 50 per cent of total output at 80 to 85 per cent efficiency, depending on state of coke market.

TEST-BENCH EFFICIENCY (T)

6. 1. 2. This is defined as the ratio of the heat output of a fuel-burning appliance under optimum conditions (as to rated output, etc.) in the laboratory, to the

thermal equivalent of the energy delivered to, or the fuel consumed by, the appliance.

This factor is one which can be determined by experiment for particular appliances. It will vary according to the design and size of the appliances—hence the "spread" of figures in column (T) of Tables 6 (2a) and 6 (2c). These may be regarded as reasonably representative of the test-bench measurements for appliances of up-to-date, though not of novel, type.

REDUCTION FROM TEST-BENCH EFFICIENCY (FOR CONTINUOUS HEATING) (R)

6. 1. 3. A difficult question which has to be taken into account is the fact that domestic fuel appliances (other than electrical apparatus) when in use in practice will, in general, give a service of a varying degree of efficiency below that of the test-bench efficiency measured under laboratory conditions. The factors which have been taken into account in estimating the value of R include loss of efficiency due to the use of a fuel for which the appliance was not designed, the collection of dirt and scale on heating surfaces, imperfect combustion, air-leaks in boiler settings, and combustion at rates other than the optimum.

There is considerable difficulty in arriving at a fair evaluation of this factor, which is essentially empirical. The "spreads" for this factor, included in column (R) of Tables 6 (2a) and 6 (2c), must be regarded only as approximations.

INTERNAL TRANSMISSION EFFICIENCY (CENTRAL HEATING ONLY) (Q)

6. 1. 4. This factor is the ratio of the quantity of heat reaching the radiator or room-warming appliance to the quantity of heat leaving the boiler to supply that appliance. It applies only to central heating installations, and depends entirely on the arrangement and length of the piping in the buildings. This transmission loss is not, in general, entirely lost to the house.

APPLIANCE EFFICIENCY (A)

6. 1. 5. This factor may be defined as the ratio of the heat delivered by an appliance to the potential heat equivalent of the fuel or energy it consumes. It is derived arithmetically from T, Q, and R by the formula:

$$A = T \times Q \times \frac{100 - R}{100}$$

This factor is used for the calculations of fuel consumption set out in Chapter 7 (paragraph 7. 2. 3. 2).

6. 2. COAL ECONOMY EFFICIENCY

6. 2. 1. The purpose of the preceding analysis has been to arrive at a figure for expressing the proportion of the heat in the original coal which is finally delivered to a room heated by different methods. This factor, here termed "coal economy efficiency" (C), may be defined as the ratio of the quantity of heat delivered by the appliance to the room under normal domestic conditions, to the quantity of heat in the coal burnt to provide the heat, or consumed in producing the gas, coke, or electricity used in the appliance. The factor is derived arithmetically from P and A by the formula:

$$C = P \times A.$$

i. Continuous heating.

The coal economy efficiency figures in Table 6 (2a) refer to conditions of continuous heating.

ii. Intermittent heating.

Much domestic heating is intermittent in character, and certain types of appliance are more suited than others for use in this way. It is therefore necessary to provide a measure of the appliance and coal economy efficiency resulting from use under such conditions, and this has been done in Table 6 (2b).

Four cases are taken, which may be regarded as characteristic of cold and mild weather (40° F. and 55° F.), and for two periods of occupation of the room (6 hours and 1 hour). The estimates are based on an average hourly heat input to the room of 6000 B.Th.U. per hour and 2000 B.Th.U. per hour (for the two types of weather condition), over the periods of 6 hours and 1 hour. Hence the tasks for each appliance are to provide totals of 36,000 B.Th.U., 12,000 B.Th.U., 6000 B.Th.U., and 2000 B.Th.U. respectively. The approximate amounts of fuel to fulfil these tasks with various appliances are known, and hence the efficiency figures A and C can be calculated.

The solid-fuel appliances need to be lighted some time before the commencement of the period of occupation, since they do not immediately give the required output of heat. During this time, however, the room is partially warmed, and the fuel burned is not wholly wasted. While it is reasonable to light a solid-fuel appliance for long periods of use, it is not reasonable to light one specially for periods as short as one hour. If, however, the appliance is already alight and providing background heating, it might quite well be used for intermittent heating for short periods.

6. 2. 2. No one column of efficiencies provides a complete picture of practical conditions, but a study of all, which cover continuous heating and intermittent heating (for medium and short periods and for high and low heat input to a room), should give guidance as to the order of overall efficiency likely to be obtained in any practical set of circumstances.

6. 2. 3. The coal economy efficiency figures in Tables 6 (2a), 6 (2b), and 6 (2c), though of importance and interest from the point of view of the efficient use of coal and the conservation of coal resources, must be read with the greatest care, and subject to a number of qualifications:

a. The coal economy efficiency figures do not reflect the factor of variations in the quality of coal used for different purposes. In particular, it should be emphasized that electricity generating stations make considerable and increasing use of low-grade coal, which does not at present find an easy outlet for other purposes. From this point of view, therefore, it is not possible to judge the merits of electricity for domestic heating in terms of the coal economy efficiency figures in Tables 6 (2a), 6 (2b), and 6 (2c) alone. Similarly, the carbonization of coal at the gasworks results in the production of many valuable materials, some of which serve as raw materials for the plastics and chemical industries.

b. Many of the figures in these Tables are necessarily approximations, and this is expressed by the "spreads" in the Table. There is particular uncertainty in the values in column (R) (reduction from test-bench efficiency), a factor which by its nature must be purely empirical.

c. Another difficult question is the calculation of the production efficiency (P) in the case of gas and coke. As explained in 6. 1. 1 above, two alternative figures are given, resulting in two alternatives in column (C).

d. Generally speaking, domestic fuel-burning appliances are not required in practice to provide a continuous output corresponding to test-bench conditions. The amount of heating required will vary with the outside temperature and with the occupancy and use of the various rooms; the period over which heating is

required may be long or short; hot water may be required in large or small quantities at varying intervals, thus affecting the proportion of the heat in the water which is lost from tanks or pipes before use; the temperature of the water may vary from tepid to boiling with only proportionate effect upon the efficiency calculations, but with overriding effect upon usefulness. Some idea of the contrast which consideration of these factors must impose is gained by a comparison between the sections of Tables 6 (2a), 6 (2b), and 6 (2c), dealing with continuous and intermittent heating.

e. These Tables and the computation of coal economy efficiency do not take into account various features of methods of heating which are of great personal importance to the householder and also of national importance. For instance, an appliance which requires 10 minutes of attention per day causes in the aggregate a very large expenditure of time (measured in man- or housewife-hours about 600 million per annum), and convenient appliances can therefore save a considerable amount of this waste effort. Controllability is also an important factor in preventing excess heating and consequent waste of fuel. Methods of heating dependent on gas and electricity provide the merits of convenience, cleanliness, and controllability.

f. Another factor which should be taken into account is the economic loss to the community by atmospheric pollution. In assessing the contribution of any method of heating buildings, account must be taken, not only of the general smoke emission from solid-fuel fires, but also of the pollution within the home and, in the case of gas, coke, and electricity, that caused at the gasworks or power station. The more efficient appliances within each class will generally give rise to the lesser amount of pollution. When the fuel consumption of a particular appliance is known, the pollution emitted into the air may be estimated by means of the data in Appendix 4.

g. The analyses in this Report are intended as contributions to the general knowledge and understanding of domestic heating problems, rather than as solutions of specific questions in connection, for instance, with particular local housing schemes.

h. There can in fact be no very precise estimate of the efficiency of methods of heating from the national point of view, for that would mean the almost impossible task of assessing the efficiency of all the different methods in actual use throughout the land; furthermore, the result, if it could be got, would only apply to the particular date at which such assessment was attempted. As technology advances, the methods of heating and their efficiencies change. An attempt to estimate efficiencies, based on certain measurements and assumptions, is made in this Chapter, but it has to be realized that technical improvements might alter the order in which different methods of heating are placed according to their efficiency, and it is well to bear such possibilities in mind when considering future developments in domestic heating. There are thermal losses in the production of gas and electricity which will undoubtedly decrease with technical advances in the production processes. The process of gas manufacture may be modified to provide greater flexibility in regard to the relative amounts of gas and coke produced, and supplies from small and less efficient works may gradually be replaced by supplies from more efficient works. The efficiency of turbines has steadily increased and, with the possibilities of taking in heat at still higher temperatures, efficiencies of electricity generation should further improve. The conversion of the thermal energy of coal into electrical energy and back into heat is a process which, thermodynamically, involves the discharge of a high proportion of heat which cannot be used, but combined thermal and electric schemes can help to raise the efficiency with which coal can be burnt to provide power and heat concurrently. This will form the subject of a special Report.

EFFICIENCY OF DIFFERENT METHODS OF HEATING

Table 6 (2a). Continuous Heating

This Table and Tables 6 (2b) and (2c) must be read in the light of Chapter 6, and particularly of the qualifications set out in 6. 2. 3.

Appliance	Production Efficiency P		Assumed Internal Transmission Efficiency Q	Test-Bench Efficiency T	Reduction from Test-Bench Efficiency in Practice R[1]	Appliance Efficiency A	Coal Economy Efficiency C	
	%		%	%	%	%	%	
Electric fires, radiators, and convectors (free-standing)	18		100	100	0	100	18	
Electric thermal storage with hot-water radiators	18		90–75	95	0	86–71	16–13	
	(a)[2]	(b)					(a)	(b)
Flueless gas heater	73	48	100	90	0	90	66	43
Gas fire	73	48	100	50–40	10–20	45–32	33–23	22–15
Gas fire with convection	73	48	100	65–55	5–15	62–47	45–34	30–23
Gas-fired boiler (large) with hot-water radiators	73	48	90–75	85–75	0–5	76–54	55–39	36–26
Gas-fired boiler (small) with hot-water radiators	73	48	90–75	80–70	0–5	72–50	53–36	35–24
Coke-fired boiler (large), automatic feed, with hot-water radiators	73	100	90–75	80–65	5–10	68–44	50–32	68–44
Coke-fired sectional boiler (small) with hot-water radiators	73	100	90–75	70–55	20–30	50–29	36–21	50–29
Coke in open coke grate	73	100	100	35–25	20–30	28–18	20–13	28–18
Coke in closed stove	73	100	100	70–60	10–20	63–48	46–35	63–48
Coke in closeable fire (i) open	73	100	100	60–50	15–25	51–38	37–28	51–38
(ii) closed	73	100	100	70–60	15–25	60–45	44–33	60–45
Coal in open grate	—		100	30–20	15–25	25–15	25–15	
Anthracite in closed stove	—		100	70–60	10–20	63–48	63–48	
Coal in closeable fire (i) open	—		100	55–45	15–25	47–34	47–34	
(ii) closed	—		100	65–55	15–25	55–41	55–41	
Coal-fired boiler (large), automatic stoking with hot-water radiators	—		90–75	80–65	5–15	68–41	68–41	
Coal-fired sectional boiler (small) with hot-water radiators	—		90–75	70–50	15–30	54–26	54–26	

Notes:

[1] Overheating, which may occur in some cases, has not been allowed for in estimating the factor R. It may be taken into account either by a separate factor, or by further increasing the value of R by some arbitrary amount. With built-in appliances there may be losses due to conduction through the wall. The efficiency in practice may then be reduced by from 5 to 15 per cent.

For the explanation of (a) and (b) in Columns P and C, see " Production Efficiency " in 6. 2. 3.

TABLE 6 (2b). INTERMITTENT HEATING

	6-HOUR PERIOD						1-HOUR PERIOD					
	6000 B.TH.U. PER HOUR			2000 B.TH.U. PER HOUR			6000 B.TH.U. PER HOUR			2000 B.TH.U. PER HOUR		
	Fuel Used	Appliance Efficiency A	Coal Economy Efficiency C	Fuel Used	Appliance Efficiency A	Coal Economy Efficiency C	Fuel Used	Appliance Efficiency A	Coal Economy Efficiency C	Fuel Used	Appliance Efficiency A	Coal Economy Efficiency C
Electric fires (free-standing)	11 kwh.	96	17 [1]	4 kwh.	88	16 [1]	2 kwh.	88	16 [1]	¾ kwh.	78	14 [1]
Flueless gas heaters	85 cu. ft.	85	(a) 62 [2] (b) 41	30 cu. ft.	80	(a) 58 (b) 38	15 cu. ft.	80	(a) 58 (b) 38	6 cu. ft.	67	(a) 49 (b) 32
Gas fires	180 cu. ft.	40	(a) 29 (b) 19	70 cu. ft.	34	(a) 25 (b) 16	35 cu. ft.	34	(a) 25 (b) 16	15 cu. ft.	27	(a) 20 (b) 13
Gas fires with convection	130 cu. ft.	55	(a) 40 (b) 26	50 cu. ft.	48	(a) 35 (b) 23	25 cu. ft.	48	(a) 35 (b) 23	11 cu. ft.	36	(a) 26 (b) 17
Coke in open coke grates	13 lb.	22	(a) 16 (b) 22	9 lb.	11	(a) 8 (b) 11	Not suitable					
Coke in closeable stoves (open)	9 lb.	32	(a) 23 (b) 32	7 lb.	14	(a) 10 (b) 14	Not suitable					
Coal in open grates	15 lb.	18	18	9 lb.	10	10	Not suitable					
Coal in closeable stoves (open)	8 lb.	33	33	7 lb.	13	13	Not suitable					

Notes. [1] Power stations normally use low-grade coal (see paragraph 6. 2. 3. a).
[2] (a) and (b) in Columns C, see "Production Efficiency" in 6. 1. 1.

General. In common practice, fuel or energy consumptions may easily exceed the above estimates by 25 per cent, according to the particular appliance and the care in operation.

TABLE 6 (2C). EFFICIENCY OF DIFFERENT METHODS OF WATER HEATING

APPLIANCE	PRODUCTION EFFICIENCY P		INTERNAL TRANSMISSION EFFICIENCY Q	TEST-BENCH EFFICIENCY T	REDUCTION FROM TEST-BENCH EFFICIENCY IN PRACTICE R	APPLIANCE EFFICIENCY A	COAL ECONOMY EFFICIENCY C
Electric heater	18		[1]	100	0 [2]	100	[1]
	(a) [4]	(b)					
Gas storage unit	73	48	[1]	80–75	0–5 [2]	80–71	[1]
Gas heater, instantaneous	73	48	[1]	80–70	0–5 [2]	80–66	[1]
Small coke-fired independent boiler	73	100	[1]	50–40 [3]	25–35 [2]	38–26	[1]
Small anthracite-fired independent boiler	—		[1]	50–40 [3]	25–35 [2]	38–26	[1]

Notes. [1] The internal transmission efficiency of water-heating systems depends on the individual installations. No figure for this, or for the coal economy efficiency can therefore be given.

[2] Does not take account of dead water in the appliance or pipes, nor of losses from storage vessels. These losses have been separately evaluated in Chapter 3.

[3] Efficiency for water-heating only. Any warming of the room in which the boiler stands is incidental.

[4] (a) and (b) in Column P, see "Production Efficiency" in 6. 1. 1.

CHAPTER 6. ANNEX A

EFFICIENCY OF ELECTRICITY GENERATION

The calculation below of coal required to produce at consumers' premises a unit quantity of electricity is based on the Electricity Commissioners' returns for authorized electricity undertakings in 1937 (year ending March 1938 for local authorities).

i.	Total kWh. generated, including output from water power, oil and gas engines, etc.	23,011 million kWh.
ii.	kWh. purchased	169 ,, ,,
iii.	Total kWh. generated plus purchased	23,180 ,, ,,
iv.	Total kWh. sold to consumers (as metered at consumers' premises, including hydro-electric power)	19,263 ,, ,,
v.	kWh. generated by coal and coke only (includes very small output from oil-fired boilers)	22,046 ,, ,,
vi.	Corresponding kWh. sold to consumers (in same proportion as (iv) to (iii) above)	18,300 ,, ,,
vii.	Coal and coke consumed (includes very small quantity of fuel oil expressed as equivalent coal)	14·0 million tons

The weighted average calorific value of all coal used in electricity generating stations in 1937 was approximately 11,300 B.Th.U. per lb. The average efficiency of generation was, therefore,

$$\frac{22{,}046 \times 3{,}415}{14 \times 2{,}240 \times 11{,}300} = 21 \text{ per cent.}$$

Allowing for losses in transmission to consumers' premises, the production efficiency is

$$\frac{18{,}300 \times 3{,}415}{14 \times 2{,}240 \times 11{,}130} = 18 \text{ per cent.}$$

The transmission losses allowed in this calculation include "unaccounted-for" losses due to inaccuracies of meterings as these cannot be separately assessed. These figures represent the state of affairs for the country as a whole in 1937, but some of the larger and more efficient generating stations have operated at efficiencies of 26 per cent and over, corresponding to a combined generation and external transmission efficiency of 22 per cent.

Hydro-electric generation also has an important bearing on coal economy. In the year 1937-8, about 3 per cent of the units generated in the United Kingdom were produced by water power (with a corresponding saving in coal requirements) and this figure will, of course, be increased if the proportion of hydro-electric generation increases.

CHAPTER 6. ANNEX B

EFFICIENCY OF THE GASWORKS PROCESS

It is no simple matter to calculate the thermal efficiency of the gasworks process and gas distribution. On the one hand, about 10 per cent of the gas sold is obtained not from gasworks coal but is surplus from coke-ovens or is made from oil. On

the other hand, the gasworks process yields a variety of products, and the allocation of the proportion of the coal required for each is arbitrary and artificial.

This is best illustrated by analysis by two different methods of the Board of Trade returns for authorized gas undertakings (1937 is the most recent year published):

a. The total gas (less coke-oven gas), coke, and tar sold by the gas undertakings had a thermal content less than that of the coal and oil used. The thermal loss could be distributed proportionally to the thermal content of the several products, as follows:

Total volume of gas sold		316,400	million	cu. ft.
Less volume of coke-oven gas purchased		28,028	,,	,,
		288,372	,,	,,
Converted to average calorific value of 475 B.Th.U. per cu. ft. and allowing 3 per cent for temperature and pressure correction	=	1,410	,,	therms[1]
Thermal content of coke and tar recovered for sale	=	2,710	,,	therms[2]
Total thermal content of products	=	4,120	,,	,,
Thermal content of coal carbonized (300 therms per ton)	=	5,595	,,	,,
Thermal content of oil used (1·7 therms per gallon)	=	56	,,	,,
Total thermal content of coal and oil	=	5,651	,,	,,
Hence the total thermal loss in the gasworks process	=	1,531	,,	,,

Hence, in this year, the gasworks recovered 4120 million therms out of the 5651 million therms in coal and oil processed—a recovery of 72·9 per cent.

b. An alternative method is to claim that the primary object of the gasworks process is to produce gas, and that all other products, including coke, are incidental but inevitable. All heat losses in the process must therefore be debited against gas.

According to this point of view, the production of 1410 million therms of gas involved a loss of 1531 million therms or a total requirement of 2941 million therms for the production of 1410 million therms of gas, equivalent to a thermal efficiency of 48·0 per cent.

The calculated figure for gasworks efficiency includes an allowance (derived from the Board of Trade returns, after correcting for temperature and pressure changes) of 4·5 per cent of the total gas made in respect of gas unaccounted for. Only a small part of this arises from actual leakage, the greater part being due to inaccuracies of metering, but as the separation of the two factors is indeterminate the whole is considered to be a transmission loss.

These figures represent the state of affairs for the country as a whole in 1937, but some of the larger and more efficient works have been operating at efficiencies, determined by method (a), of 80 per cent or over.

[1] This correction arises from the fact that the statutory declared calorific value and the statutory measure in cubic feet are both related to gas at 30 in. Hg. pressure and 60° F. (saturated), while the readings of consumers' meters are not so corrected. Consumers on this account receive normally about 3 per cent greater thermal value than is charged to them, and this appears in the Board of Trade returns as an apparent loss.

[2] Including thermal value of the benzole which was in some cases recovered as such and in others sold in the gas.

CHAPTER 7

THE CHOICE OF METHODS OF HEATING

7. 1. SOME FACTORS IN THE CHOICE OF APPLIANCES

7. 1. 1. There are many different ways of providing the necessary heating services in a house, and the right choice for any particular case will depend on many factors. Some of these factors cannot be measured; in this class are personal tastes and local custom. Other factors can be expressed quantitatively, and it is the purpose of this Chapter to indicate methods of evaluating some of these quantitative factors which affect the choice of methods of heating. In particular, studies are made of:

a. The estimation of the amount of fuel needed to supply the heating services (room heating, water heating, and cooking).

b. The capital cost of supplying and installing the various appliances and the cost of maintaining them in working order.

c. The labour involved in the use of different methods.

7. 1. 2. Economy in fuel consumption is of direct importance to the householder financially, and it is also of general importance to the nation as a whole, because coal—the ultimate source of all the fuels discussed—is only produced with effort and is a wasting asset. The capital costs of the equipment are important, particularly to local authorities and the Government, as an element in the cost of building the house, and to the householder, as a potential addition to the rent (paragraph 7. 3. 1).

7. 2. ESTIMATION OF THE AMOUNT OF FUEL NEEDED TO SUPPLY THE HEATING SERVICES

LACK OF STATISTICAL DATA

7. 2. 1. There is a lack of authoritative statistical data on which estimates of the domestic fuel consumption could be based. At best, such statistics would be difficult to obtain, since they would be of little value unless related to particulars of the type of house, the circumstances of the occupant, the appliances installed and so on. Nevertheless, it is felt that steps should be taken, if possible, to collect such statistics related to comparable conditions. Not only would such information be of great value in itself, but it would also provide an essential correlation between, on the one hand, the general experience of users of fuel and, on the other hand, laboratory work on appliances and calculations based thereon, such as those described below.

It has therefore been necessary to make estimates, and in this Chapter one method is described of estimating the fuel consumption required to provide the standard of heating recommended in Chapter 2 in dwellings equipped with various alternative combinations of appliances.

Inevitably a number of assumptions had to be made. The calculations are, therefore, hypothetical and are intended to be illustrative of the method. It would be wrong to draw from them over-simplified conclusions, particularly in relation

to specific localities. Nevertheless, no process is subject to scientific investigation unless it is studied under prescribed conditions.

The assumed conditions on which the calculations are based are defined in paragraph 7. 2. 2; and the method employed is explained in paragraph 7. 2. 3. The results of the computations are set out in column 3 of Table 7 (4), and the necessary qualifications to the Table are given in paragraph 7. 2. 4.

7. 2. 2. BASIS OF THE CALCULATIONS OF FUEL CONSUMPTION

7. 2. 2. 1. *Combinations of Appliances.* The comparison between the different methods of providing the heat supply for houses is not a simple one, *e.g.* as between the use of coal, gas, or electricity. For any given house, the fuel services—room heating, water heating, and cooking—must in general be supplied by a "combination" of different appliances using different fuels. Indeed, a particular service may often be provided by two different appliances, depending on the season. A large number of different combinations is thus theoretically possible.

In the calculations which follow, it has been necessary to select certain alternative combinations, broadly suitable for providing the standard of heating envisaged in Chapters 2 and 3. Details as to the appliances included in the various combinations are set out in Annex A to this Chapter. Three features of these combinations should be referred to:

a. As postulated in the standards of heating suggested in Chapters 2 and 3, the appliances are designed to provide background heating throughout the house, with "topping-up" as necessary (see paragraph 7. 2. 2. 4 below).

b. Where room heating is by solid fuel, it is provided by a "closeable fire" *i.e.* a stove with doors which can be opened to give a view of the fire. The advantages of this type of appliance are that it is both economical of fuel, as compared with the conventional open fire, and may be adapted for the provision of convection heating by warm air, which facilitates background heating.

c. For the purpose of these calculations, coke and not coal has been taken as the fuel for the solid-fuel burning appliances, and the figures in Table 7 (4) for solid fuel refer throughout to coke. Bituminous coal or anthracite can, however, be used instead of coke in many cases. The consumption of anthracite will be comparable with that for coke; but that of bituminous coal will normally be somewhat greater.

7. 2. 2. 2. *Size of House and Household.* The calculations are necessarily related to a particular house with a definite standard of accommodation in terms of number and size of rooms. Some details as to the house are given in paragraph 3. 1. 3, and it can be regarded as reasonably typical of pre-war local authority housing.

As in Chapter 3, the heat requirements have been estimated in terms of a family of four—two adults and two children.

7. 2. 2. 3. *Construction of the House.* The construction of the house is, as shown in detail in Chapters 3 and 4, of great importance as determining the degree of thermal insulation. The construction assumed for the purpose of these calculations corresponds roughly with pre-war building methods and provides only a medium degree of insulation (see paragraph 3. 1. 3 and Table 3 (5)). If the higher standards of insulation envisaged in Chapter 4 were adopted, the estimated fuel consumptions would be lower for the same heating standard. This would be particularly the case for those methods of heating which can provide very low

minimum rates of combustion, or, like gas and electricity, are easily controlled. In such cases a reduction of 10–20 per cent in the heat requirements of a room could be obtained with higher standards of insulation.

7. 2. 2. 4. *Standard of Heating.* The calculations of fuel consumption are throughout in terms of the standards of heating recommended in Chapter 2. These presuppose background heating throughout the house (*i.e.* the maintenance of a *minimum* temperature of 45°–50° F.), 24 hours a day, with topping-up where necessary. The temperatures to be attained in the various rooms are assumed to be as follows:

TABLE 7 (1)

ASSUMED TEMPERATURE CONDITIONS

Living room:	Background heating to 50° F. Topping-up to 65° F. for a total of 9½ hours per day (divided into 3 periods—morning, midday, and evening), and 55° F. for 6 hours in 2 periods.
Bedrooms:	Background heating to 50° F. Topping-up to 55° F. for 2 hours per day (divided into 2 periods—morning and evening).
Hall:	Background heating to 50° F.; daytime 55° F.
Kitchen:	Background heating to 50° F. Topping-up to 60° F. for 12 hours per day.
Bathroom:	Background heating to 50° F.

For details see Table 2 (1) (paragraph 2. 1. 9). It does not follow, of course, that every household will require this standard of heating, which is only one of an infinite variety of requirements. It is, however, this standard which, it is recommended, should be capable of being met by the equipment installed, so that its fulfilment serves as a convenient example for calculations.

For water heating, requirements of hot water are assumed to be the equivalent of 250 gallons per week at a temperature of 140° F. (see paragraph 2. 3. 2).

Cooking requirements, to provide the normal meals of a family of four have been assumed (see paragraph 7. 2. 3. 6 below).

In cases of illness it may be necessary to supply additional warmth in one bedroom. On the assumption that the normal heating of the house would maintain a minimum background temperature of 50° F., the additional fuel consumption involved would be quite small. When a heating appliance is provided for a bedroom which may be used as a sick room, consideration should be given to other factors, such as cleanliness and the amount of labour and attention required, as well as to the cost.

7. 2. 3. METHOD OF CALCULATION

7. 2. 3. 1. *Heat Losses from a Room.* Given the above postulates, the thermal losses, when the various rooms of the house are heated to the assumed temperatures, have been calculated. The form of the calculation of these losses is indicated in paragraph 3. 1. 2. As is there indicated, heat losses (h) are a function of:

a. The degree-days (D) for the locality in question and corresponding to the inside temperature assumed (see paragraph 3. 1. 1. 1).

b. The hourly air-changes in the room, which depend on the degree of ventilation (V).

c. The construction of the walls, etc., of the room or building. This determines

the thermal transmittance or heat transmittance co-efficient (U) of the walls. Account is taken in this factor of the "exposure" of the building.

[For details see Annex B to this Chapter.]

One of the assumptions in the calculations was the use of degree-day figures for Kew; that is to say, the calculations are for the London climate.

7. 2. 3. 2. *Appliance Efficiency*. In order to estimate the fuel consumption of different types of appliances when the heat losses from a room are known, it is necessary to make use of the concept of appliance efficiency (A) (see paragraph 6. 1. 5). The spreads in Table 7 (4) arise from the fact that some of the quantities which affect the appliance efficiency are not accurately known (columns T and R in Table 6 (2)).

7. 2. 3. 3. *Fuel Requirements for Continuous Room Heating*. Given the estimated heat losses from a room (h) in appropriate units, and the appliance efficiency (A), the calculated fuel consumptions (F) for heating the room in question continuously to the assumed temperatures for a given period of time are obtained by the formula:

$$F=\frac{h}{A\times K}$$

where: for solid fuel K=calorific value of the fuel in B.Th.U. per lb., giving F in lb.

for gas appliances K=100,000 giving F in therms.

for electricity K=3415, giving F in kWh.

Where an appliance has an appreciable minimum output (as in the case of most solid-fuel burning appliances), the above equation cannot be applied directly, and allowance must be made for the minimum rate of combustion when the heat loss is less than the minimum output. This factor has been allowed for in the calculations in Annex C. The use of the equation also implies efficient thermostatic or manual control of the output, in order to avoid overheating (see paragraph 7. 2. 4 (d) below).

7. 2. 3. 4. *Fuel Consumption for Intermittent Room Heating*. The figures calculated as described apply only to continuous heating. If the heating is intermittent, as when topping-up is in progress, other factors have to be considered. It is not sufficient to take the heat requirements as proportional to the time for which a room is in use, because when heating is interrupted, the building cools, and pre-heating at a more rapid rate is necessary to bring the building structure back quickly to the desired temperature. No completely satisfactory method has been devised for computing the heat requirements for intermittent heating. In order to make some allowance for this factor in the computations in Annex C and Table 7 (4), the heat loss has been calculated as for the steady state (paragraph 3. 1. 2), and then multiplied by a fraction estimated from Table 3 (8). This allowance can only be approximate, as it depends on the length of the pre-heating period and the nature of the wall surfaces, and possibly also on the type of heating employed (*i.e.* whether radiant or convective). Other methods of estimating the fuel consumption during periods of intermittent heating are also available (see *e.g.* Chapter 6).

7. 2. 3. 5. *Fuel Consumption for Water Heating*. As indicated above, the calculations assume a requirement of 250 gallons per week of water at 140° F. The fuel consumption for water heating has been estimated from the heat requirements given in Table 3 (10) (Case I) for solid fuel boilers, and in Table 3 (11) for gas and electric appliances and using the efficiencies given in Table 6 (2c). Weekly

fuel consumptions are given for the insulated and uninsulated systems in Table 7 (2a) below, and they clearly show the advantages of insulation. It would be difficult, with existing independent boilers in continuous use, to achieve a consumption as low as 0·76 cwt. per week. In making the computations for Table 7 (4) the insulated system has been taken.

TABLE 7 (2a)

CALCULATED WEEKLY FUEL CONSUMPTION FOR WATER HEATING

(250 GAL. AT 140° F.)

	CONSUMPTION	
	Not insulated	Insulated
Independent coke boiler	1·54–2·25 cwt.	0·76–1·10 cwt.
Electric immersion heater	—	84 kWh.
Gas storage unit	—	3·6–4·0 therms
Instantaneous gas heater (multi-point)	3·1–3·7 therms	—

Fuel consumption in any particular instance may vary widely from the above values, which have been calculated on definite assumptions as to layout, etc. The following figures, obtained in a specific trial simulating domestic conditions, with a total usage of 260 gallons per week at 140° F., illustrate the point.[1]

TABLE 7 (2b)

WEEKLY FUEL CONSUMPTION FOR WATER HEATING IN A PARTICULAR TRIAL

Electric immersion heater	120 kWh.
Gas storage heater	6–8 therms
Instantaneous gas multi-point heater	4–6 therms
Instantaneous gas single-point heater	3–4 therms

The discrepancies between the above two Tables may arise from several causes; for instance, as regards the second Table, (a) the insulation of tank and pipes not being as good as that assumed in Chapter 3, (b) more frequent draw-off, longer pipe runs, causing greater loss of "dead water", and (c) efficiency of appliance not being as high as was assumed.

7. 2. 3. 6. *Fuel Requirements for Cooking.* The fuel requirements for cooking used for Table 7 (4) have been based on figures supplied by the fuel industries. They are given in the second column of Table 7 (3) below. As methods of using cooking appliances vary considerably, the figures given merely represent typical consumptions and should not be regarded as necessarily comparable.

[1] Solid-fuel heaters were not included in these trials.

TABLE 7 (3)

WEEKLY FUEL CONSUMPTION, AMORTIZATION AND ANCILLARY BUILDING COSTS FOR COOKING EQUIPMENT

	TYPICAL WEEKLY FUEL CONSUMPTION	COST, PENCE PER WEEK		LABOUR MINS./WEEK
		Amortization and Maintenance	Ancillary Building	
Heat storage cookers (coke) Do. (providing hot water also)	0·9 cwt. – 1·13 cwt.*	13·1–20·0	6·4	20, +70 for attention to fire
Gas cooker †	2 therms	2·4	—	20
Electric cooker	28 kWh.	4·1	—	20
Lightly insulated range with controllable fire (coke—providing hot water also)	$1\frac{1}{4}$ cwt.*	7·0–12·5	6·4	20, +70 for attention to fire

* There will be wide variations about these figures since cooking is not the sole function of these appliances.

† Also commonly used for heating small quantities of water.

The above Table also gives figures supplied by the individual industries for capital charges and maintenance costs and the time spent in cleaning and tending the appliance, subjects which are discussed in 7. 3 and 7. 4 below.

7. 2. 3. 7. *Total Annual Fuel Consumption.* Calculations based on the assumptions defined in paragraph 7. 2. 2. above and carried out by the methods outlined in paragraph 7. 2. 3. were made in order to arrive at the estimated annual fuel consumptions of several possible combinations of appliances, and the results are embodied in Table 7 (4). Details of the calculations for Combinations 1, 5, and 7 are given in Annex C to this Chapter.

The estimates of fuel consumption have not been translated into terms of actual running cost, because of the great variations in fuel prices and methods of charge in different parts of the country. Such calculations could, however, readily be made in terms of the particular fuel prices ruling in any given locality. It is estimated that in most cases the cost of fuel for providing all the heating services would be between half and three-quarters of the total running costs, including capital charges, etc.

QUALIFICATIONS TO TABLE 7 (4)

7. 2. 4. It has already been emphasized that the calculations of fuel consumption in Table 7 (4) involve a number of assumptions. It is most important that this Table should always be considered in the light of those assumptions, and that over-simplified conclusions should not be drawn from it. It should not be used in connection with a particular housing scheme without expert advice and without taking into account all the local circumstances, such as the type of houses to be erected, the climatic conditions, local preferences in regard to heating appliances, local availability of fuels, and local fuel prices. At the risk of some repetition, it is well to emphasize certain specific qualifications regarding the figures of fuel consumption in Table 7 (4):

a. The Table assumes the standard of heating outlined in Chapter 2. This is, of course, considerably higher than the average pre-war standard of the lower income groups. The assumed construction of the house, however, approximates to pre-war conditions, as regards insulation.

b. The calculations are inevitably in terms of a single house and a single set of conditions with regard to occupancy, etc. In actual practice there is, of course, a wide range of conditions, and also great variation in fuel consumption, even by apparently similarly placed families living under similar conditions. On the other hand, in order to obtain comparative figures, it is necessary to assume a single set of conditions regarding the house and its occupancy. Those chosen are considered to be reasonably typical.

c. Although the alternative combinations of appliances for which calculations have been made provide a reasonably representative range, they are not the only possible ones. For a different standard of heating, or for other family circumstances, for example, other combinations might be more appropriate. It is important, therefore, that there should be the widest possible freedom of choice for consumers between different methods of heating.

d. The heat requirement of a house is rarely constant for long, since most of the heating is essentially intermittent. In addition, weather conditions fluctuate, heat production by ancillary processes such as lighting and cooking varies, and the number of occupants of a room changes. The output of an appliance would need frequent alteration if the room temperature were to be held constant, and without thermostatic control or frequent manual adjustment of the output some degree of overheating, with a consequent waste of fuel, is almost bound to occur, particularly when the heat requirement is small (*e.g.* in spring or autumn). It would be very difficult to assess the importance of this factor quantitatively because it depends essentially on personal habits and behaviour. It is another factor accounting for variations in fuel consumption found in practice between apparently similar cases.

e. In such personal matters as the degree of comfort needed or which can be afforded, the amount of hot water used, and the method of using the domestic cooker, extremely wide variations are to be expected between various households, even where the equipment provided is identical. Experience has shown that it is not possible to estimate how much fuel any given household will use, though records of actual consumptions over a number of households do enable an average to be determined for those particular conditions. The purpose of these calculations, therefore, is not to derive an estimate of fuel consumptions or costs which will apply to every case, but rather to show how the many factors are interconnected and that they must all be taken into account when advice is given or choice is made regarding the fuel-burning equipment of dwellings.

ESTIMATES OF FUEL CONSUMPTION WITH PRE-WAR COMBINATION APPLIANCES

7. 2. 5. Combination appliances have been extensively used in the past, particularly in the North of England and Scotland, where the use of a combined space- and water-heater would not cause much inconvenience in summer. It is of interest, therefore, to make some estimate of the probable fuel consumption when some attempt is made to meet the conditions as to room heating and hot-water supply postulated above.

It is difficult to determine a satisfactory basis on which to judge a multi-purpose unit, since the various functions are not as a rule independent of one another. When the oven is in use, or when set for space heating, the amount of heat given to the boiler is less than when adjusted for water heating. The quantity of fuel likely to be used in a normal week has been estimated from the fuel consumption found in some trials (a) for maintaining the room temperature about 20° F. above the outside temperature (this is approximately the average temperature difference throughout the heating season) for a period of 14 to 16 hours, starting each day from cold; (b) for heating the room as before, and for heating the oven; and (c) for heating the room and providing hot-water supply. The amount of heat given

to the room seems to be but little affected by the setting, and the fuel consumption of all types of combination appliances (combination grate, kitchen range and back-to-back grate) is in practice much the same on all adjustments, viz. about 2 cwt. a week in normal use for 14 to 16 hours a day. (Large variations may occur in individual cases, and as much as 5 cwt. a week may sometimes be used.) In the course of a week a combination appliance burning this amount of fuel is capable of heating an ordinary kitchen or living room, of providing nearly all the required cooking facilities, and of supplying about three-quarters of the hot water recommended above.

Hot water and cooking are often supplied by other means during the summer, and in winter the service given by the range is often augmented, largely for the sake of convenience, by using a gas or electric cooker or water heater. In the trials, a small amount of gas (up to 20 cu. ft. per day) was consumed in most of the houses, chiefly for cooking breakfast. It should be borne in mind that the service given is still less than that postulated in 7. 2. 2. 4 above, as, except in the case of the back-to-back grate, only one room is warmed, and in no case is background heating provided in the hall and bedrooms. In view of this, the fuel consumption of these appliances appears rather high when compared with the similar figures in Table 7 (4) which refers to the south of England. The estimated consumptions for the appliances listed in Table 7 (4) would be somewhat higher in the north. By using a slightly larger amount of coal in a combination appliance, the additional space-heating demand in the north could be met, and also the deficiency in hot-water supply would be made up, with a consequent reduction in supplementary gas or electricity consumption. The comparison would not then be so unfavourable as at first sight appears.

Post-war appliances may be expected to show some improvement and should provide better performance and higher efficiency. The lightly insulated range with controllable fire mentioned above is an example.

7. 3. CAPITAL AND MAINTENANCE COSTS

CAPITAL COSTS

7. 3. 1. The capital cost of fuel appliances is of considerable importance as an element in the cost of building. The cost of the appliances themselves has to be considered in conjunction with the ancillary building costs, *i.e.* the expenditure on flues, the installation of gas piping, electric wiring, etc.

These capital charges are of importance from three points of view:

a. The charges will affect the financial ontlay by the body responsible for the finance of housing.

b. The charges will to some extent be reflected in the rent.

c. Broadly speaking, an efficient appliance is likely to cost more than an inefficient appliance. On the other hand, higher efficiency means lower fuel consumption and thus a smaller weekly outlay on fuei for the housewife, and a better use of coal from the national point of view. In monetary terms, therefore, where the fuel consumption is considerable, it should pay to install highly efficient appliances, because the corresponding increase in rent should at least be offset by the economy in fuel. When the fuel consumption is likely to be small (as *e.g.* in the case of fires in bedrooms) the increased cost of an efficient appliance may not be justified by the small saving of fuel which can be effected. A balance between first cost and fuel cost has in all cases to be preserved. From the national fuel economy point of view, the most efficient appliances in each class should always be used.

Amortization, Building Costs, and Annual Fuel Consumption, for Eight Combinations of Appliances, for the Standards of Heating, etc., suggested in Chapter 2, and assuming a House with Medium Standard of Insulation. See the qualifications in paragraph 7. 2. 4.

	SERVICE	APPLIANCE	ANNUAL FUEL CONSUMPTION	APPLIANCE COST: PENCE PER WEEK	ANCILLARY BUILDING COSTS: PENCE PER WEEK	LABOUR MINUTES PER WEEK
COMBINATION 1	Background heating, living rooms and bedroom	Closeable fire	16 cwt.	5·9–8·0	8·0	70
	Topping-up, living room	Closeable fire	17–23 cwt.	—	—	—
	Topping-up, bedrooms	Gas fires	33 therms	4·2	3·6	—
	Hot-water supply, includes bathroom, kitchen, and hall heating	Independent boiler	55–81 cwt.	11·1	1·9	70
	Cooking and some water heating	Gas cooker	104 therms	2·4	—	20
	Alternatives:			23·6–25·7	13·5	160
	Topping-up, bedrooms	Electric fires	363 kWh.	3·3	3·6 [1]	—
	Cooking	Electric cooker	1456 kWh.	4·1	—	20
COMBINATION 2	Heating, background and topping-up, all rooms except kitchen, bathroom, and hall	As Combination 1	{33–39 cwt. 33 therms	5·9–8·0 / 4·2	8·0 / 3·6	70
	Hot-water supply and cooking (includes bathroom, hall, and kitchen heating)	Lightly insulated range	65 cwt.	15·6–21·1	6·4	90
	Alternative:			25·7–33·3	18·0	160
	Topping-up, bedrooms	Electric fires	363 kWh.	3·3	3·6 [1]	—
COMBINATION 3	Background heating, all rooms except bathroom	Central heating (radiators)	47–82 cwt.	7·3	8·0	70
	Topping-up, living room	Gas fire	130–170 therms	1·7	1·2	—
	Topping-up in bedrooms	Not required	—	—	3·6 [1]	—
	Hot-water supply, includes bathroom heating	Hot-water boiler	48–71 cwt.	6·0	—	—
	Cooking and some water heating	Gas cooker	104 therms	2·4	—	20
	Alternatives:			17·4	12·8	90
	Topping-up, living room	Electric fire	1700 kWh.	1·7	1·2 [1]	—
	Topping-up, living room	Open coal fire	19–28 cwt.	2·1	6·4	70
	Cooking	Electric cooker	1456 kWh.	4·1	—	20
COMBINATION 4	Background heating, all rooms except bathroom	Central heating (embedded panels) from hot-water boiler	44–76 cwt.	7·3	8·0	70
	Topping-up, living room	Gas fire	150–200 therms	1·7	1·2	—
	Topping-up, bedrooms	Not required	—	—	3·6 [1]	—
	Hot-water supply, includes bathroom heating	Hot-water boiler	48–71 cwt.	6·0	—	—
	Cooking and some water heating	Gas cooker	104 therms	2·4	—	20
	Alternatives:			17·4	12·8	90
	Topping-up, living room	Electric fire	1975 kWh.	1·7	1·2 [1]	—
	Cooking	Electric cooker	1456 kWh.	4·1	—	20

[1] Gas-fire flues are provided for ventilation purposes (paragraph 8. 2. 1) and to allow freedom of choice.

TABLE 7 (4). HEATING SERVICES IN A SMALL HOUSE—*continued.*

	SERVICE	APPLIANCE	ANNUAL FUEL CONSUMPTION	APPLIANCE COST: PENCE PER WEEK	ANCILLARY BUILDING COSTS: PENCE PER WEEK	LABOUR MINUTES PER WEEK
COMBINATION 5	Background heating, living room and bedrooms	Gas fire with convection, warm air to bedrooms	80–110 therms	3·3	1·2	—
	Topping-up, living room	Gas fire with convection, warm air to bedrooms	180–240 therms	—	—	—
	Topping-up, bedrooms	Gas fires	33 therms	4·2	3·6	—
	Hot-water supply includes bathroom, kitchen, and hall heating	As Combination 1 (coke)	55–81 cwt.	11·1	1·9	70
	Cooking and some water heating	Gas cooker	104 therms	2·4	—	20
				21·0	6·7	90
COMBINATION 6	Background heating, living room	Electric convector	700 kWh.	0·9	1·2 [1]	—
	Background heating, bedrooms	Electric convector	770 kWh.	2·7	3·6 [1]	—
	Topping-up, living room	Electric fire	3300 kWh.	1·7	—	—
	Topping-up, bedrooms	Electric convectors	363 kWh.	—	—	—
	Heating hall and bathroom and water-heating	As Combination 1 (coke)	55–81 cwt.	11·1	1·9	70
	Cooking	Electric cooker	1456 kWh.	4·1	—	20
				20·5	6·7	90
COMBINATION 7	Background heating and topping-up for living room and bedrooms	As Combination 1	33–39 cwt.	5·9–8·0	8·0	70
			33 therms	4·2	3·6	—
	Heating hall	Gas convector	8 therms	1·5	1·2	—
	Heating bathroom	Gas towel rail	36 therms	1·2	—	—
	Heating kitchen	Gas convector	32 therms	1·2	1·2	—
	Water heating	Gas water heater	160–210 therms	4·3–12·7		
	Cooking and some water heating	Gas cooker	104 therms	2·4	—	20
				20·7–31·2	14·0	90
COMBINATION 8	Background heating and topping-up for living room and bedrooms	As Combination 1	33–39 cwt.	5·9–8·0	8·0	70
			363 kWh.	3·3	3·6 [1]	—
	Heating hall	Electric convector	210 kWh.	0·9	—	—
	Heating bathroom	Electric towel rail	960 kWh.	0·9	—	—
	Heating kitchen	Electric convector	850 kWh.	0·9	—	—
	Water heating	Immersion heater in tank	4360 kWh.	6·5	—	—
	Cooking	Electric cooker	1456 kWh.	4·1	—	20

TABLE 7 (5)

PRE-WAR COST OF TYPICAL APPLIANCES INCLUDING AMORTIZATION AND MAINTENANCE*

(Figures in brackets in first column denote life of appliance in years)

	INITIAL COST, INCLUDING FIXING	AMORTIZATION COST, PENCE PER WEEK	MAINTENANCE COST, PENCE PER WEEK	AMORTIZATION AND MAINTENANCE COST, PENCE PER WEEK
Room Warming Appliances	£ s. d.			
Closeable fire with convector jacket (15–20)	12–15 0 0	3·9–6·0	0·5	4·4–6·5
Open coal fire and surround (20)	5 0 0	1·6	0·5	2·1
Living room gas fire and surround (20)	3 15 0	1·2	0·5	1·7
Bedroom gas fire and surround (20)	2 15 0	0·9	0·5	1·4
Living room electric fire (15)	3 5 0	1·3	0·4	1·7
Bedroom electric fire (15)	2 5 0	0·9	0·2	1·1
Ducts from living room to bedroom (20)	4 0 0	1·3	0·2	1·5
Radiator for hall, towel rail, piping, valves expansion tank and insulation (40)	8 5 0	1·8	1·3	3·1
Complete panel warming installation for background heating; radiators (40),	20 (radiators)	4·3	1·0	7·3
boiler (15)	5 (boiler)	2·0		
Central heating (radiators): radiators (40)	20 (radiators)	4·3	1·0	7·3
boiler (15)	5 (boiler)	2·0		
Convector gas fire (20)	4 0 0	1·3	0·5	1·8
Electric convector (30)	3 5 0	0·8	0·1	0·9
Gas convector (20)	2 10 0	0·8	0·4	1·2
Gas towel rail (20)	4 0 0	1·3	0·2	1·5
Water-Heating Appliances				
(1) *Circulating Systems*				
Indirect storage cylinder, piping and valves (25)	11 0 0	3·1	0·5	3·6
Independent boiler with smoke pipe (15)	5 0 0	2·0	0·5	2·5
Gas circulator (20)	7 10 0	2·4	1·2	3·6
Lagging (25)	6 0 0	1·7	0·2	1·9
(2) *Storage Systems*				
Storage cylinders and piping (25)	9 0 0	2·5	0·5	3·0
Immersion heater (20)	5 10 0	1·8	0·5	2·3
Lagging (25)	3 10 0	1·0	0·2	1·2
18-gallon gas storage heater (20)	16 10 0	5·4	2·2	7·6
12-gallon storage heater (electric) (20)	14 0 0	4·5	1·0	5·5
Piping for above (25)	1 0 0	0·3	—	0·3
1½-gallon sink water heater (electric) (20)	4 0 0	1·3	1·0	2·3
(3) *Instantaneous Heaters*				
Sink water heater (gas) (10)	5 5 0	2·9	1·4	4·3
Multi-point water heater (gas) (10)	16 0 0	8·9	3·5	12·4
Cooking				
Heat storage cooker (20–25)	45–60 0 0	12·6–19·5	0·5	13·1–20·0
Lightly insulated range (15–20)	20–30 0 0	6·5–12·0	0·5	7·0–12·5
Gas cooker (20)	6 0 0	2·0	0·4	2·4
Electric cooker (20)	8 10 0	2·8	1·3	4·1

* The figures for all appliances relate to those supplied in bulk and fitted in the houses at the time of their erection, and the prices are pre-war.

The figures given in Table 7 (5) include provision of taps, switches, regulating valves, piping, and lagging where necessary. When room and water heating are effected by one appliance, it is necessary to add the appropriate figures, *e.g.* central heating with radiators and water heating by an indirect cylinder will have a capital cost of £25+£11.

MAINTENANCE COSTS

7. 3. 2. In addition to the capital costs of the appliances themselves, and of the installation (ancillary building costs), estimates have to be made of the cost

of maintaining the appliance in working order, and of making provision for replacement when unserviceable or out of date.

In Tables 7 (5) and 7 (6) are set out estimates of the various costs involved, obtained largely from the fuel and appliance industries. Amortization of appliances has been taken over the "life" of the appliance at 3½ per cent compound interest, and of the ancillary building costs, over a period of 40 years, at 3½ per cent compound interest, to accord with pre-war normal practice in local authority housing.

TABLE 7 (6)

PRE-WAR ANCILLARY BUILDING COSTS FOR HEATING APPLIANCES

	INITIAL COST	AMORTIZATION COST, PENCE PER WEEK	MAINTENANCE COST, PENCE PER WEEK	AMORTIZATION AND MAINTENANCE COST, PENCE PER WEEK
Ground floor chimney	£25	5·4	1 *	6·4
First floor chimney	£17	3·7	1 *	4·7
Coal store	£5	1·1	0·5	1·6
Concrete block flue for gas appliances	£5	1·1	0·1	1·2
Asbestos cement flue	£4	0·9	1 *	1·9

* Includes sweeping.

7. 4. LABOUR

In order to obtain a fair comparison between different methods of heating, it is necessary to take into account the amount of labour involved in attending to the appliances, and in cleaning up the dust and dirt which they sometimes cause. The figures in Table 7 (4), which are necessarily arbitrary, are intended to cover time spent in lighting, re-fuelling, and ash removal, and general cleaning of the appliance and its setting. These were based on a figure of 10 min. per day for all solid-fuel burning appliances, to cover time spent in attending to the fire but not general cleaning of the kitchen. The labour involved with gas and electric appliances (apart from cookers, discussed below) is very small and has been neglected. In the case of cooking equipment, the labour involved consists mainly in the removal of fats, etc., from ovens and hotplates. The time required for this is almost entirely a function of the method of cooking, and a figure of 20 min. a week has been assumed for all cookers. (In the case of solid-fuel cookers, this will be in addition to the time spent in looking after the fire and in general cleaning of the appliance, making a total of 90 min. a week for these appliances.)

7. 5. CONCLUSION

The analysis made in the present Chapter shows that no detailed recommendations can be made as to the appliances which should be provided in each and every house. This conclusion is reinforced by consideration of the technical progress which is now being made in all fields of fuel and power production and use. It can be predicted with confidence that progress will be made which will in the long run lead to raising the standards of domestic warmth and comfort with a reduced consumption of fuel. In order, therefore, to enable the fullest advantage to be taken of all such developments, it would appear desirable to provide in all houses the basic facilities for the use of the various alternative sources of supply. The

data in the Tables in the present Chapter should be regarded as directed to showing the scope for improvement and to the stimulation of research and technical progress, rather than to the guidance of a housing authority in the solution of its specific problems.

CHAPTER 7. ANNEX A

PARTICULARS OF COMBINATIONS SELECTED

The combinations of appliances for which calculations have been made are as follows:

1. A closeable fire or semi-closed stove fitted with convection jacket is used to provide background heating for living room and bedrooms. The fire would be "open" to provide radiant heat when topping-up is required in the living room. The jacket would supply warm air to the living room and also, through ducts, to the bedrooms. Warm-air heating, of which this is an example, is popular in other countries. There may, however, be certain practical difficulties, such as dust deposition at the exits from the ducts, but this has not been commented on abroad, and the trouble may be overcome by care in design. Several such proposals have been advanced in this country in recent years, and the results of practical experience are awaited with interest. The bedrooms would be topped-up by gas or electric fires.

Hot water is provided by an independent boiler in the kitchen coupled to a storage vessel in the linen cupboard. This boiler would also serve a radiator in the hall and a towel rail in the bathroom.

Cooking is effected with a gas or electric stove.

2. In this combination a lightly insulated range with controllable fire replaces the gas or electric cooker and the hot-water boiler of Combination (1). The remaining equipment is unaltered.

3. Only one solid-fuel appliance is used—a small hot-water supply boiler, which provides background heating for the whole house by means of hot-water radiators. Topping-up is effected by gas or electric fires. The heating boiler also provides hot water by means of a calorifier or indirect cylinder in the linen cupboard, and warms a towel rail in the bathroom.

Cooking is by gas or electricity.

4. Background heating in the living room and hall is provided by embedded ceiling panels, which also serve as floor panels for two bedrooms. A separate floor panel is provided in the third bedroom. The panel temperature is not more than about 70° F., to avoid excessive radiation on the head. The panels are heated by means of a calorifier and a hot-water supply boiler, which also provides the required hot water and warms a towel rail in the bathroom.

Topping-up is effected by gas or electric fires, and cooking is by gas or electricity.

5. The living room is heated by a convector gas fire, and warm air from the same appliance is conveyed by ducts to provide background heating in the bedrooms. Gas fires are used for topping-up in the bedrooms. An independent boiler supplies hot water and serves a radiator in the hall and a towel rail in the bathroom. Cooking is by gas.

6. Electric convectors are used for background heating in the living room and bedrooms and also for topping-up in bedrooms. An electric fire is used for topping-up in the living room. An independent boiler supplies hot water and serves a radiator in the hall and a towel rail in the bathroom. Cooking is by electricity.

7. The living room and bedrooms are heated by a closeable fire, as in Combination (1), the remaining requirements being provided by gas appliances.

8. The living room and bedrooms are heated as in Combination (1), the remaining requirements being provided by electric appliances.

It will be noted that in most of the combinations listed, only one solid-fuel burning appliance is used.

The fuel consumption for a house on the same assumptions using gas only may be obtained by taking the figures for Combination (7), replacing the consumption for living room and bedroom warming by that for Combination (5). Similarly for an electrically heated house, the figures of Combination (8) should be used in conjunction with Combination (6).

CHAPTER 7. ANNEX B

DEGREE-DAY CALCULATIONS

The heat input necessary to a room or building depends directly on the rate of heat loss from the room or building, and the number of degree-days in the heating season. The first stage, therefore, in the calculation of fuel consumption should be the determination of degree-days for the conditions obtaining. The usual method of doing this is to subtract the mean outside temperature for each month, for the particular locality, from the mean inside temperature required. It has already been pointed out in Chapter 3 of the Report that the inside temperature of a house is normally about 5° F. above the outside temperature, due to fortuitous heat gains from solar radiation, cooking, water heating, lighting, and the metabolism of the occupants. The temperature difference as calculated above may therefore be decreased by 5° F., and the resultant figure multiplied by the number of days in the month will give the degree-days for the month. This computation should be made for all the months when the mean temperature is more than 5° F. below the desired internal temperature, in order to obtain the number of degree-days per annum. These calculations are shown in Table 7. A for inside temperatures of 50° F. and 52·5° F. respectively.

TABLE 7. A. DEGREE-DAYS AT KEW

MONTH	MEAN DAILY TEMPERATURE AT KEW *	INTERNAL TEMPERATURE WITHOUT HEATING	DEGREE-DAYS FOR 50° F. INTERNAL TEMPERATURE	DEGREE-DAYS FOR 52·5° F. INTERNAL TEMPERATURE
October	49·9° F.	54·9° F.	—	—
November	44·0	49·0	30	105
December	40·3	45·3	145	222
January	38·9	43·9	190	263
February	40·1	45·1	137	207
March	42·4	47·4	81	158
April	47·3	52·3	—	6
May	53·4	58·4	—	—
Annual Total			583	961

* Mean daily temperature for other localities may be obtained from the *Book of Normals*.

The next step in determining the heat requirement is to ascertain the heat loss per deg. F. temperature difference as described in paragraph 3. 1. 2. Multiplication of the hourly heat loss by the number of degree-days and by 24 will give the total annual heat requirement.

The heat losses from a building calculated as in paragraph 3. 1. 2 are strictly applicable only to the steady state; that is, when constant temperatures are maintained inside and outside the building. Although some mathematical studies of

the flow of heat under fluctuating conditions of temperature have been made, no completely satisfactory method for practical use has as yet been developed. It has, however, been shown that fuel consumption is inversely proportional to the mean daily external temperature, and accordingly, in determining heat losses in these calculations, the assumption is made that the mean daily temperature could be taken as the external temperature.

It should be noted that the degree-day method does not allow for the fact that an amount of heat added over a long period is not as effective in warming a room as the same amount added in a short period. For example, the total heat gain in the bedrooms during the 24 hours is greater than the calculated loss during the topping-up periods (Table 3 (6)), but, during the two hours when topping-up is wanted in the bedrooms, this heat gain from the living room is in mid-winter insufficient to raise the temperature to 55° F., and additional heating will be necessary. Some proportion of the heat gain does, however, contribute to the background heating of the bedrooms, and an arbitrary proportion of 75 per cent has been allowed in Tables 3 (6) and 3 (7).

CHAPTER 7. ANNEX C

DETAILED COMPUTATION OF FUEL CONSUMPTION

for Combinations 1, 5, and 8

COMBINATION 1

Background heating for living room and bedrooms.	Closeable fire with warm-air duct to bedrooms.
Topping-up, living room.	Closeable fire.
Topping-up, bedrooms.	Gas or electric fires.
Hot-water supply; bathroom, hall, and kitchen heating.	Independent boiler, with radiator in hall, and towel rail.
Cooking.	Gas or electric cooker.

COMBINATION 5

Background heating, living room and bedrooms.	Convector gas fire with warm-air duct to bedrooms.
Topping-up, living room.	Ditto.
Topping-up, bedrooms.	Gas fires.
Hot-water supply; bathroom, hall, and kitchen heating.	Independent boiler, with radiator in hall, and towel rail.
Cooking.	Gas or electric cooker.

COMBINATION 8

Background heating, living room and bedrooms.	Closeable fire with warm-air duct to bedrooms.
Background heating, hall.	Electric convector.
Background heating, bathroom.	Electric-heated towel rail.
Topping-up, living room.	Closeable fire.
Topping-up, kitchen	
Topping-up, bedrooms.	Electric fires.
Hot-water supply.	Electric storage unit.
Cooking.	Electric cooker.

COMBINATION 1

BACKGROUND HEATING

Using a closeable fire to warm the living room and bedrooms, it has been assumed

that such an appliance has a minimum fuel consumption of $\frac{1}{2}$ lb. per hour. During background heating the fire will be closed and its efficiency may range from 60 per cent to 45 per cent, say, 52 per cent average (Table 6 (2)). For a consumption of $\frac{1}{2}$ lb. of coke per hour, the calorific value of the coke being 12,000, the hourly heat output is $12{,}000 \times 0{\cdot}52 \times 0{\cdot}5 = 3{,}120$ B.Th.U.

It may be calculated (from Table 3 (6)) that the hourly heat loss per degree Fahrenheit difference of temperature between inside and outside is 431 B.Th.U. for the living room and bedrooms; hence the fire burning at its minimum rate will maintain a temperature difference of 3120 divided by 431 or about 7° F. and this figure added to the mean internal temperatures for each month shown in Table 7. A. gives mean internal temperatures ranging from 51° F. in January to 56° F. in November. Assuming that the fire is used continuously from November to March inclusive (151 days), the fuel consumption for background heating would be $\frac{1}{2} \times 24 \times 151$ lb. = 16 cwt.

The heat loss from the hall may be calculated from Table 3 (6) to be 46·5 B.Th.U. per degree-hour. A radiator having 5 sq. ft. of heating surface is proposed for the hall. Such a radiator with a mean water temperature of 150° F. will emit about 150 B.Th.U. per sq. ft. per hour, the whole radiator giving off 750 B.Th.U. per hour. A temperature rise of $\frac{750}{46{\cdot}5} = 16°$ F. will be obtained. Thus the average temperature in the hall from November to March would range from 60° F. to 65° F., which is rather higher than required. The connections to the radiator will be about 20 ft. long. Assuming they are $\frac{3}{4}$-in. diameter and insulated, they will emit about 250 B.Th.U. per hour; the total heat requirement for this radiator will then be 1000 B.Th.U. per hour.

The bathroom is fitted with a towel rail comprising about 7 ft. of 1-in. diameter pipe which, with a mean water temperature of 130° F., will have an emission of about 375 B.Th.U. per hour throughout the year. This will give a temperature rise of 375/38·9 or about 10° F., the mean temperature varying from 54° F. in January to 65° F. in October. The total emission, including $\frac{1}{2}$-in. diameter insulated connections about 20 ft. long, will be 540 B.Th.U. per hour.

The annual heat emission from the towel rail will be $540 \times 24 \times 365 = 4{\cdot}73 \times 10^6$ B.Th.U. and from the hall radiator $1000 \times 24 \times 151 = 3{\cdot}62 \times 10^6$ B.Th.U. Table 6 (2c) shows that a small coke-fired boiler has an efficiency ranging from 38 per cent to 26 per cent. The heat delivered to the water in B.Th.U. per pound of coke burned is 12,000 × efficiency. The fuel consumption for the radiator will therefore range from 7 to 10 cwt.; and for the towel rail from 9 to 14 cwt.—a total of 16 to 24 cwt. per annum.

There will be sufficient heat given off by the boiler and its pipes to warm the kitchen, and no special provision is made.

TOPPING-UP

The extra amount of heat required to maintain 65° F. for $9\frac{1}{2}$ hours and 55° for 6 hours per day instead of 50° F. in the living room amounts to $8{\cdot}63 \times 10^6$ B.Th.U. per annum. Since topping-up is intermittent, the figures in Table 3 (8) may be applied.[1] If the temperature of 65° F. were maintained continuously, *i.e.* for 24 hours, the heat required would be

$$\frac{8{\cdot}63 \times 10^6 \times 24}{15{\cdot}5} = 13{\cdot}4 \times 10^6 \text{ B.Th.U. per annum.}$$

[1] Table 3 (8) strictly applies to a single period of heating in each 24 hours, starting from cold; but bearing in mind that in this case the room is not initially cold, and also that each of the three pre-heating periods during the day would necessitate a progressively smaller fuel consumption, it is felt that as a first approximation Table 3 (8) may be used direct, as if the topping-up were confined to a single period of similar duration.

Reference to Table 3 (8) shows that the total heat input to a room for an occupation period of $15\frac{1}{2}$ hours will be about 85 per cent of that needed for continuous heating for 24 hours; hence the heat needed for topping-up is:

$$13{\cdot}4\times 10^6\times 0{\cdot}85=11{\cdot}4\times 10^6 \text{ B.Th.U. per annum.}$$

The fire will be open when topping-up is in progress, and its efficiency ranges from 51 per cent to 38 per cent (Table 6 (2)). The annual fuel consumption will be:

$$F=\frac{11{\cdot}4\times 10^6}{12{,}000\times \text{efficiency}\times 112}=17 \text{ to } 23 \text{ cwt.}$$

Background heating gives a temperature rise of about 7° F., so that topping-up in the bedrooms will normally be necessary only in December, January, February, and March, *i.e.* the 121 days when the room temperature is below 55° F. The bedrooms require topping-up night and morning, and the heating problem becomes one of personal warming. It is suggested that the appliances in the bedrooms would have an average use of half an hour night and morning, or a total of 1 hour per day.

Electric fires rated at 1 kW. or gas fires burning 0·09 therms per hour would be suitable. These will consume 363 kWh. or 33 therms in 121 days in the three bedrooms.

In view of the reasonable temperatures provided, no topping-up is necessary in the hall and bathroom.

WATER HEATING

Table 3 (10) shows that the amount of heat needed for an insulated system for Case I is 386,000 B.Th.U. per week. The boiler efficiency ranges from 38 per cent to 26 per cent and hence the fuel consumption for hot water per annum is:

$$\frac{386{,}000\times 52}{12{,}000\times \text{efficiency}\times 112}=39\text{–}57 \text{ cwt.}$$

This consumption is rather less than has been suggested as practicable with existing appliances, but the towel rail provided will increase it by 9 to 14 cwt. per annum, giving a more reasonable total.

COOKING

Cooking consumptions and costs may be taken directly from Table 7 (3).

A summary of the items making up the total fuel consumption for Combination 1 is given in Table 7 (4).

COMBINATION 5

BACKGROUND HEATING IN LIVING ROOM AND BEDROOMS

Table 3 (6b) gives the total annual net heat loss during background heating in the living room and bedrooms as 5·05 million B.Th.U.

A modern convector gas fire has an efficiency ranging from 62 per cent to 47 per cent (Table 6 (2)). The fuel consumption for background heating is, therefore:

$$F=\frac{5{\cdot}05\times 10^6}{100{,}000\times \text{efficiency}}=80 \text{ to } 110 \text{ therms.}$$

Without thermostatic control, some overheating may result, particularly when the heat requirement is low; but no allowance for this has been made in Table 7 (4).

TOPPING-UP

As with Combination 1, the extra heat requirement of the living room if topping-up were continuous would be $11 \cdot 4 \times 10^6$ B.Th.U. per annum.

The efficiency of the convector gas fire ranges from 62 per cent to 47 per cent, so that the annual fuel consumption is:

$$F = \frac{11 \cdot 4 \times 10^6}{100{,}000 \times \text{efficiency}} = 180 \text{ to } 240 \text{ therms.}$$

As in Combination 1, 33 therms would be required for topping-up in bedrooms.

WATER HEATING

This is done as in Combination 1, and the fuel consumption is, therefore, 39 to 57 cwt. of coke. Background heating of hall and bathroom requires a further 16 to 24 cwt.

COOKING

The gas consumption for cooking is taken from Table 7 (3). It is assumed to amount to 2 therms per week or 104 therms per annum.

COMBINATION 8

BACKGROUND HEATING AND TOPPING-UP IN LIVING ROOM AND BEDROOMS

A closeable fire is used, as in Combination 1, and the fuel consumption is, therefore, 33 to 39 cwt. of coke. For the bedrooms, the electricity consumption will amount to 363 kWh.

BACKGROUND HEATING IN THE HALL

Table 3 (6) shows that $0 \cdot 72 \times 10^6$ B.Th.U. per annum are required to keep the hall at the desired temperature.

An electric convector is used in this combination and, taking the efficiency as 100 per cent, the energy consumption is:

$$F = \frac{0 \cdot 72 \times 10^6}{3415} = 211 \text{ kWh.}$$

BACKGROUND HEATING IN THE BATHROOM

Assuming that a towel rail of a size equal to that included in Combination 1 is used, the hourly heat emission will be 375 B.Th.U. The rail is assumed to be in use 24 hours per day, 365 days per year, so that the annual heat output will be $375 \times 365 \times 24 = 3 \cdot 28 \times 10^6$ B.Th.U. The annual electricity consumption is:

$$F = \frac{3 \cdot 28 \times 10^6}{3415} = 960 \text{ kWh.}$$

BACKGROUND HEATING IN THE KITCHEN

Some topping-up will probably be required, and it has been assumed that an electric fire would be used, consuming 846 kWh.

WATER HEATING

The energy consumption for water heating is taken directly from Table 7 (2a), giving a consumption of 84 kWh. per week, *i.e.* about 4360 kWh. per annum.

COOKING

The electricity consumption for cooking is taken directly from Table 7 (3). It is assumed to amount to 28 kWh. per week or 1456 kWh. per annum.

CHAPTER 8

THE VENTILATION OF DWELLINGS

8. 1. VENTILATION BY FLUES

WALL VENTILATORS AND FLUES

8. 1. 1. Many observations have been made on the ventilation of rooms by ordinary flues, gas fire flues, and wall ventilators. Even with no fire alight, the two former in general are found to give greater ventilation than the latter. When rooms are warmed, the ventilating effect of flues is increased, but the wall ventilator is not materially affected. Wall ventilators are more affected by weather conditions than flues and are apt to cause unpleasant draughts which frequently result in their being blocked up.

In a room with windows closed and flue sealed, about 700 to 800 cubic feet of air is changed per hour, due to leakage under the door and through cracks round the opening lights of windows, though on occasion the ventilation may be much less than this. With a single wall ventilator, the volume of ventilating air is increased by about 10 per cent, but the minimum ventilation required by two persons (1200 cubic feet per hour) could not be obtained with any practicable increase in the area of the wall ventilator.

VENTILATION INDUCED BY CERTAIN APPLIANCES

8. 1. 2. Some heating appliances, such as a coal or gas fire, may induce excessive ventilation. (In the case of the gas fire this can be avoided by proper installation, and in the case of a coal fire a partial remedy can be found by correct design of the throat and by the use of an adjustable canopy.) The excessive draughts which are thus caused can be prevented by building a fresh-air duct to admit air in front of the fire. Care would have to be taken to design the duct so as to exclude vermin and prevent its being choked up with ashes, etc., and to prevent draughts when the wind is in the direction of the opening.

Some appliances require very little air for combustion, and are consequently fitted with a small-diameter flue pipe. The induced ventilation may then be insufficient in a room occupied by more than two persons, but this may often be corrected by admitting air to the main flue.

VENTILATION OF KITCHENS, ETC.

8. 1. 3. The ventilation of the kitchen presents a special problem. When cooking is being done, steam and odours are given off and these should not be allowed to permeate the rest of the house. It is recommended below that a solid-fuel flue should be provided in all kitchens. In the case of some solid-fuel cookers, provision is made to remove fumes by a vent to the flue. Where this is not the case, and with gas and electric cookers, a hood should be provided and ventilated to the solid-fuel flue.

Bathrooms and w.cs. can be adequately ventilated by a properly designed window. When not situated on an outside wall, a ventilating shaft with positive ventilation is essential.

8. 2. RECOMMENDED PROVISION FOR VENTILATION

Provision should be made for ventilation irrespective of the method of heating, and one way of effecting such provision is by the flues mentioned in 1. 3 above, namely:

Living room: Flue (minimum 50 sq. in.[1])
Kitchen: Flue (minimum 50 sq. in.[1]) and ventilated hood over cooker if no other provision is made.
Bedrooms: Flue (30 sq. in., or 50 sq. in.[1] where open fire installed).

In addition, bathrooms and w.cs. require a flue (minimum 18 sq. in.) if there are no windows.

In all cases, windows should be designed to make possible such control as to permit ingress of a small quantity of fresh air under all atmospheric conditions, and so that fresh air can be admitted near ceiling level so as to reduce draughts. This is specially important if flues are provided, for the flue opening will normally be near the floor.

The practice of opening the windows of a room for a short period has much to commend it. With a door and window open, very high rates of ventilation can be obtained, and the time required for one air-change may be from 2 to 5 minutes. It will be seen, therefore, that there is no necessity to keep windows wide open for long periods; in fact this practice leads to a waste of fuel in warming unnecessarily large quantities of air, and in cooling down the structure, which subsequently has to be re-warmed.

CHAPTER 9

SUPPLEMENTARY SERVICES ASSOCIATED WITH THE HEATING OF DWELLINGS

9. 1. CLOTHES WASHING

PROVISION FOR LAUNDRY

9. 1. 1. The Heating of Dwellings Inquiry showed that 73 per cent of the households questioned did all their washing at home, so that laundry is an important item in the domestic economy. It was somewhat surprising to note from the survey that only a very small proportion of the people who lived within ten minutes' walk from a communal laundry made use of the service available—less than 15 per cent. The service was more used by housewives in the higher income groups and more by those with larger families.

Adequate and convenient laundry facilities promote cleanliness and comfort of the family. Unfortunately, in many cases, the existing arrangements in the home cannot be said to be satisfactory, either because there is an insufficient supply of hot water, or on account of the inconvenience of clothes drying.

Improvements in the design of communal laundries have in some cases overcome the psychological objections to such installations, and in all suitable cases, such as

[1] This may be complied with by an 8-in. circular flue or an 8-in. square flue; but a square flue of the minimum area would not be satisfactory.

blocks of flats and housing estates in urban areas, every endeavour should be made to encourage the provision of such facilities, and thus obviate the need for washing appliances in individual premises.

The Heating of Dwellings Inquiry shows that the main methods of water heating for laundry purposes at present are the coal-heated copper or set-pot, gas or electric boilers, or pans and kettles on the fire or range—in that order. When a separate wash-copper is installed it should be not less than 7 gallons capacity. The main point is that there should be a convenient source of supply of ample hot water for home laundry, and this has been dealt with in an earlier chapter.

CLOTHES DRYING AND AIRING

9. 1. 2. Clothes drying is important, and normally in wet weather it has been done by hanging the clothes in front of the only fire which has been available to the family. A heavy wash being dried in this way encroaches on the limited space available in the warmed room and fills the house with moisture and the smell of drying clothes. A properly designed built-in drying cabinet would do much to ease the situation, and is regarded as a desirable amenity. Apart from its use on wash-day, it could also be used for the occasional drying of outdoor clothes, provision for which has been neglected in the past. Such a built-in drying cabinet need not take up a great deal of space in the house, and would preferably be situated near to where the washing is done. The cabinet would require an independent heater, either gas or electric, and should be ventilated to the outside air independently of the kitchen.

Facilities must also be provided for airing clothes and linen. This is normally carried out in a cupboard built round the hot-water tank; and even when the tank is lagged, the remaining heat losses from the tank and pipes in the cupboard raise the temperature inside sufficiently to air clothes.

HEATED TOWEL RAIL

9. 1. 3. A heated towel rail would serve to keep the bathroom reasonably warm throughout the day, and would reduce the risk of frozen water pipes. This may be readily contrived by a secondary circulation system from the hot-water storage tank, particularly if the latter is near the bathroom. Where the tank is immediately above the boiler, the same secondary circulation could be used for both towel rail and linen cupboard. Excessive lengths of piping should be avoided. A towel rail may also be heated by gas or electricity.

9. 2. REFUSE DISPOSAL

The disposal of refuse is related to heating inasmuch as the equipment now in general use in houses serves as an incinerator. Open fires are often receptacles for paper, while independent boilers consume a considerable amount of kitchen refuse. Owing to its water content, the useful heat from such refuse is negligible, but its domestic incineration lightens the load on the local refuse disposal arrangements.

9. 3. OTHER SERVICES

Facilities should be provided for the use of irons, hot-plates, refrigerators, and vacuum cleaners. Clothes washing machines should also be provided for where electricity is available.

CHAPTER 10
RURAL HOUSING

10. 1. SPECIAL CONDITIONS OF RURAL LIFE

It was estimated by the Scott Committee on Land Utilization in Rural Areas that out of a total population of about 41 million in England and Wales, no less than 6 million lived in isolated farmhouses, hamlets, and small villages. Of this 6 million, between 2 and $2\frac{1}{2}$ million live outside the villages. Rural housing thus forms a quite appreciable proportion of the whole problem. So far, the suggestions made and the conclusions reached refer to urban housing. The conditions of rural life are somewhat different from those of town life, and as a consequence some of the recommendations need modification.

The chief points which should be borne in mind are:

a. The preference of the outdoor worker for a high equivalent temperature during periods of relaxation. This is of special interest in rural areas, where outdoor workers predominate.
b. The lack of cheap or easily available supplies of gas or electricity in some cases.
c. The higher transport charges for solid fuel.
d. The prevalence of wood and peat as fuels, and the use of paraffin or other hydrocarbons.
e. The lack of certain communal services, *e.g.* laundry, sewage, and main water.
f. The slightly lower temperature, greater exposure, and greater dampness in rural districts.
g. The necessity for frequent drying of clothes.

The improvement of rural housing conditions will be largely dependent on the rapidity with which public utility services can be made available. The Scott Committee recommends, amongst other points :

a. The maintenance of agricultural wages on a basis comparable with those of industry in the towns.
b. Extension of main water, gas, and electricity supplies and sewage systems.
c. Greater storage facilities for fuel, food, etc.

10. 2. HEAT REQUIREMENTS OF RURAL DWELLINGS

10. 2. 1. For the same temperature conditions in the various rooms, the heat requirement of a typical sheltered rural dwelling is of the same order as that of the urban house considered in Chapter 3, but in many cases a number of factors tending to increase the heat demand are operative and, on the whole, it is likely that a rural house will require slightly more heat than an urban house.

The lack of main water supply and sewage systems in some areas limits the amount of both hot and cold water that can be used, particularly in dry seasons, but if circumstances permit, the quantities of hot water should not be less than those recommended in Chapter 2, since the conditions of rural life are likely to produce more dirt on the clothing and person. With the same size of family, there will probably be little difference in the heat demand for cooking as between urban and rural dwellings.

FACTORS AFFECTING HEAT REQUIREMENTS

10. 2. 2. It has been noted that a number of factors may result in an increased demand for heat in rural houses as compared with urban dwellings. Two of these factors may be briefly considered here.

In view of the cheapness of land in most rural areas, single-storey buildings have been common in the past. The heat loss from such buildings will generally be somewhat greater than from a two-storey building of similar construction and accommodation.

The siting of a house has an effect on the heat losses (Chapter 3). It is often possible in siting a rural dwelling to exercise a certain amount of choice, and when this is the case, sites with a sunny aspect and sheltered from the wind by trees, in the lee of a hill, or in valleys, would preferably be chosen. As far as possible, exposed hillsides and unprotected sites should be avoided. Farm buildings themselves, if suitably disposed, may afford a considerable degree of protection for the house.

The generally greater heat losses from rural houses which tend to increase the consumption of fuel, together with the higher cost of that fuel, render economy a very important consideration in rural dwellings. Structural insulation is, therefore, even more important than for urban houses, and the standards of insulation suggested in Chapter 4 should be regarded as minima. In many cases (particularly those on the more exposed or damp sites) it would be worth while to spend even more on the insulation than is the case with town houses.

10. 3. VENTILATION STANDARDS

The common standard of ventilation in country dwellings is usually less than that in comparable houses in towns. This may be because:

a. A higher degree of warmth is desired by outdoor workers, even at the expense of fresh air.

b. The higher cost of fuel and lower wages makes fuel conservation more important.

c. There is greater need for excluding excessive quantities of damp air.

The ventilation is doubtless inadequate in many cases, and the standards for rural houses should not be lower than the minimum rates defined earlier in this Report.

10. 4. EQUIPMENT IN RURAL HOUSES

It appears desirable to consider the heating and ventilation of rural houses on two bases, namely:

a. That main utility services are available.

b. That main utility services are unlikely to be available in the near future.

When main gas, electricity, and water supplies and sewage systems are available, the rural cottage may have the same equipment as the urban house, and the application of the recommendations for urban housing can be made without many reservations.

Under condition (b), solid fuels, particularly coal, wood, and peat, will be the main source of heat, and adequate storage accommodation should therefore be provided. The solid-fuel appliances recommended for urban houses will be equally suitable for rural houses, but in addition the development of appliances for burning wood and peat efficiently should be encouraged. Peat-burning

ranges in which good efficiency has been attained have recently been developed in Ireland, and should have an application in some districts here.

Paraffin will probably still be required for lighting and for summer cooking, and efficient methods of using it should be further developed. In some cases paraffin is now replaced by butane, propane, or other hydrocarbon gases, which have advantages over it in respect of cleanliness, though the cost is greater. Either, of course, may be replaced by gas or electricity where supplies of the latter commodities are available. (See Appendix 8.)

Proper provision for laundry should be made in all cases—a wash-boiler is the minimum requirement. It is particularly important in view of the predominance of outdoor occupations that there should be reasonable facilities for drying clothing.

CHAPTER II
FOREIGN PRACTICE

II. 1. INTRODUCTION

It is of some interest to investigate methods of heating and house construction in European countries and America, and to compare them with normal British practice. In many countries, coal supplies are less abundant than in Britain, and they must needs strive after efficiency to conserve coal. The very severe climates of many countries has forced them to develop suitable appliances, and to pay heed to the requirements of heat insulation in the design and construction of their houses.

The International Housing Association met at Prague in 1935, and the papers presented give a very fair picture of the development of low-cost housing towards the end of the inter-war period in various parts of Europe. Unfortunately, the details given relate mainly to the planning and construction of the dwellings, and information on the heating and cooking appliances is meagre. Some additional data have been obtained from nationals of several countries who were available for consultation. Recent information has also been obtained from Canada and from the Federal Housing Authority (U.S.A.). The Health Organization of the League of Nations has dealt with standards of warmth in the various countries.

II. 2. STANDARDS OF WARMTH

In France the conditions for warmth in a building are evaluated by means of the "resultant temperature" scale—a scale which takes account of wet- and dry-bulb temperature, air velocity, and radiation. The suggested conditions for warmth are 61° to 65° F. resultant temperature.

In Germany the conditions desired for warmth for sedentary occupations are given as 63° to 65° F. air temperature, 25 to 40 per cent relative humidity, and an air velocity of 20 to 60 ft./min.

The conditions desired in Sweden are an air temperature not less than 61° F., 30 to 60 per cent relative humidity, and the air velocity not exceeding 60 ft./min.

The American Society of Heating and Ventilating Engineers has introduced the "effective temperature" scale to express warmth; and it takes account of wet- and dry-bulb temperature and air movement. The numerical value is that temperature of still saturated air which would produce the same feeling of warmth as is experienced in the enclosure considered. On this scale, it is suggested that the desirable effective temperature in winter is 66° F. (corresponding approximately to an "equivalent temperature" of 70° F., Chapter 2) and in summer 71° F.

11. 3. CLIMATIC CONDITIONS

Table 11 (1) below shows the number of degree-days in Great Britain, United States, Russia, and some other European countries. The base temperature depends on the indoor temperatures normally desired, and is in each case that used in the particular country. In all cases the number of degree-days, and therefore the heating load, is substantially greater than that in Great Britain.

(It should be noted that the number of degree-days alone does not indicate the range or rate of temperature variations. The variable nature of the British climate tends to make flexibility of the method of heating of greater importance than it is in some other countries. The humidity of the air, which also has a bearing on the suitability of different types of heating, is not taken account of in computing degree-days.)

TABLE 11 (1). COMPARISON OF DEGREE-DAYS IN VARIOUS COUNTRIES

DEGREE-DAYS IN	BASE TEMPERATURE (° F.)		
	55	60	65
Great Britain	3100 (N) 2400 (S)	4750 (N) 3750 (S)	5550 (Kew)
U.S.A.			6290 (Central) 5350 (E)
Germany	6860 (E) 6660 (W)		
Russia	9810 (Moscow)		
Holland	5240 (Flushing)		
Norway	7450 (Bergen)		
Austria	6280 (Vienna)		
Poland	7030 (Warsaw)		
Switzerland	5860 (Geneva) 6450 (Zurich)		
Czechoslovakia	6700 (Brno)		

11. 4. HOUSE CONSTRUCTION

In most European countries great importance is attached to the proper insulation of houses. 38 cm. (15 in.) of solid brickwork (or the equivalent thickness of hollow block or perforated brick) is the minimum usually employed in Central and Eastern Europe, and it may be as much as 20 in. or more. In many cases there is additional insulation, particularly on exposed elevations. In Germany, Sweden, and Czechoslovakia the minimum thickness of a solid wall is prescribed by regulation (9 to 21 in. in Germany, according to district; and 18 in. in Stockholm and Prague); and the thermal resistance of alternative constructions must not be lower than that of the minimum brick wall. Ground floors may be either solid or suspended; but insulation is again used, either as a component layer of a solid floor, or as a filling to board and joist floors. Cork, sand, and slag are widely used for these purposes. Roofs are of solid reinforced concrete, hollow-beam or timber construction. Concrete roofs have additional cork or slag insulation (usually about 3 in.) and timber roofs have a boarded attic floor, sometimes filled with slag or other loose fill.

Timber constructions are also used in parts of Europe, and these are designed to provide a high degree of thermal insulation. In America and Canada the study of insulation has been very extensive, and low-density slab materials are widely used. $3\frac{5}{8}$ in. of rock wool (or equivalent) is often used for the insulation of dwellings. Aluminium foil also is rapidly coming into widespread use in North America, particularly for insulation of roofs against solar heat.

Double windows are very common throughout Europe and North America. The commonest design in Europe is two single windows in one frame; but the "storm-sash," developed in the United States, is occasionally found.

In some countries particular attention is paid to the possibility of obtaining cross-ventilation of all rooms; and special ventilating shafts are sometimes provided in kitchens, w.cs., and bathrooms.

II. 5. HEATING EQUIPMENT

ROOM WARMING

II. 5. I. Stoves, solid-fuel cooking ranges, and central heating systems are the commonest means of warming found in the Continental countries. At present the most favoured type of appliance in small domestic buildings is the closed stove, which may be either in metal or in ceramic tiles. It seems to be the case that, in one form or another, it has been found the most economical. It comes within the means of the working man, and it is equal to the task of assuring adequate warmth in the house. The fuel used is, in many cases, wood or peat; but bituminous coal, coke, and briquettes made from brown coal are also used.

Domestic stoves are usually lighted in the morning, allowed to burn briskly for a few hours, and then all air inlets are closed completely, so that heat is first gradually stored in the material of the appliance—which may be quite considerable if ceramic ware is used—and then given out slowly for the remainder of the day. Continuous-burning stoves are also in use.

When stoves are employed, they may be used either to heat the room in which they are situated, or alternatively to warm air which is then distributed through the house by ducts. Some stoves are built into the partition walls, and so may heat two or more rooms. When cooking is done by a solid-fuel appliance, separate heating of the kitchen is not usually provided, although a stove in the partition wall may be used.

As an example, the very simple, almost standard, type of workman's house in Germany has a solid-fuel cooking range of the independent or self-setting type, and closely connected with it is a ceramic-ware stove which heats the living room adjoining. The stoking of the living room stove is done from the back in a position immediately adjoining the range.

Another example is found in some houses recently erected near Zürich, in which the only space heater is a closed stove, at ground-floor level, and stoked from the entrance hall. The stove is enclosed on all sides, so that it operates in a shaft little more than 2 ft. square. The flue from the stove is of metal, and rises vertically in the shaft surrounding the stove, connecting with a brick flue which runs straight from the basement to above the roof. This is the only flue in the house, and in addition to receiving the products of combustion from the heating stove, it serves the laundry water heating boiler in the basement. Warm air from the shaft in which the stove is situated is delivered through gratings, not only to the living room, but also to the hall and to each of the bedrooms.

In some countries it is permissible to connect two, but not more than two, stoves to the one flue. The installation of separate stoves in each room severely restricts the possibility of variations in planning, as the attempt is always made to have, near the centre of the house, a single stack which groups all flues, and the stoves must be situated so that they connect with these flues. Where a block of flats is designed for heating with this system, the number of flues required makes a very big stack, with consequent waste of floor space. (An interesting development is the Shunt system of flue construction which has been used in Belgium. Fires or ranges on alternate floors of a block of flats are connected to a single flue.)

Central heating seems to have developed extensively in Switzerland, Czecho-

slovakia, and the Western European countries, and is growing in favour (particularly for flats and tenements), although it is somewhat more expensive than the closed stove. In Germany a system of central heating has been used in which air is warmed by a stove in the basement of a block of flats and is delivered by ducts to the separate dwellings. It is said to be very economical. In France and some other countries a solid-fuel burning appliance is obtainable which does the cooking and provides heating in the living room, and at the same time, by means of a heat-exchanger, heats the water for the bath and sink, and also a radiator system, up to a number of six radiators.

Some of the central heating systems for groups of dwellings or blocks of flats (notably in Prague and Zürich) are supplied from a common source (district heating on a small scale). Larger district heating schemes are in use in Russia, the United States, and Germany, and it may be noted that the recent installations of steam-driven electricity generating plant in Russia have been combined with district heating schemes.

On the Continent gas and electricity do not appear to be used on a very large scale for the primary heating of the house; but supplies are often provided and may be used for additional radiant heating when desired. In some cases, however, gas heating stoves have been employed, while in Norway, where coal is expensive and hydro-electric power is available, there is a growing tendency to use electricity for all heat services. The open fire so much favoured in this country is a luxury usually reserved for the well-to-do; although it is often used in Southern Europe with wood as the fuel.

In the United States the heating equipment is very varied, practically every type from single-outlet warm-air furnaces to fully automatic central heating plant having been used. Warm-air heating is found in the region of the Great Lakes and the Middle West; hot-water heating is more prevalent on the Eastern seaboard; and fireplaces are found in houses in the belt extending from North Carolina to Arkansas, although where automatic equipment has been installed, the fireplace is seldom used. A large number of convector-type open fires have been designed. Due to the high degree of insulation and weather-tightness of the construction, and to the supply of natural gas, there has been an increase in the use of gas-fired appliances. Automatic stokers for small units have been developed, and have the advantage that they may be designed to burn a wide range of bituminous coals. Stoves are being developed to burn bituminous coal smokelessly. Stringent legislation has been introduced in New York, St. Louis, and other cities to prevent atmospheric pollution. Owing to the abundant and cheap supplies of oil, there has been a tendency in recent years towards the use of oil-fired furnaces on account of their great convenience; but the recent rationing of oil has caused much attention to be given to automatic coal-fired equipment to replace oil burners. For this and other reasons, a considerable amount of testing and development of stoves and water-heating apparatus has been carried out by the National Bureau of Standards.

WATER HEATING

11. 5. 2. In the housing schemes described at the Prague conference, storage systems for hot-water supply were rarely used. Single-point sink- and bath-heaters for gas and electricity were usually employed, although some multi-point appliances were also installed. Coal geysers were sometimes used. In some areas a central supply is offered in flats, even extending to a modified district scheme, steam being taken from a central station and used in calorifiers in each block of flats. When centrally heated domestic hot water is supplied in flats in Germany, even those for the working class, no attempt is made to meter the supply, which is covered by the rental charge. In Norway electricity has been used to provide central hot-water supply for flats.

No information is available as to the quantity of hot water required in the various European countries; but it should be noted that communal or central laundries are often provided in new housing schemes, often with electric washing-machines.

American authorities have suggested that 175 to 290 gallons of hot water per house are required per week. The normal temperature for hot-water supply in the United States is from 140° to 180° F.

COOKING

11. 5. 3. A solid-fuel fired range, with a closed fire, is often used abroad. Sometimes the solid-fuel range is combined with a gas cooker, gas being used not only for boiling rings, but also to heat at least one oven, when the fire is out, or when additional heat is needed. Stoves which heat the living room and are also used for cooking (in the kitchen) are fairly common. Gas and electricity are much used for cooking in the Western European countries; and they are coming more and more into favour in Central and Eastern Europe. Charcoal is used as a fuel in some European countries.

Appliances using any one of the three fuels are found in North America. Solid-fuel appliances are nowadays of the closed fire type.

CHAPTER 12

THE DEVELOPMENT, INSTALLATION, AND OPERATION OF HEATING APPLIANCES

12. 1. DEVELOPMENTS IN APPLIANCES

No study of the problem of the heating and ventilation of dwellings would be complete without some reference to the modern developments in heating appliances. The various Installations Committees (Solid Fuel, Gas, and Electrical) have considered appliances in detail, and for information as to the preferred types of appliances, reference should be made to the Reports of these Committees. It is useful, however, to draw attention to some of the chief points which merit consideration.

SOLID-FUEL APPLIANCES

12. 1. 1. The solid-fuel industry in the past had fallen somewhat behind gas and electricity in the development of appliances for the smaller house. This may have been due in part to the abundance in Britain of cheap coal, with the result that there has been little incentive to the economical use of coal. The solid-fuel industry is fully alive to the question, and developments may be expected in the post-war period.

As a broad generalization, it seems that many solid-fuel burning appliances were deficient in the means provided for regulating the rate of combustion. Means for accurate control of the primary air-supply is believed to be an essential part of a solid-fuel appliance, to achieve quick response, a low minimum rate of combustion, and overnight burning. De-ashing devices should also be incorporated. The use of automatic stoking, or of hopper or magazine feed, would reduce considerably the labour of re-fuelling, and in some cases may also lead to an economy of fuel. The use of a convector device, making use of some of the heat in the flue gases, to supplement the radiation from a stove or fire, should lead to increased efficiency

and is recommended. Excessive ventilation can be reduced by the use of a fresh-air duct (see paragraph 8. 1. 2). Increased efficiency, improved design of appliances and a wider use of smokeless fuels should enable a reduction in the amount of atmospheric pollution to be achieved. For water heating by solid fuel, a more limited range of boiler output is favoured, variations in demand being more satisfactorily met by an adequate storage capacity. A central supply is advocated for large blocks of flats, rather than individual solid-fuel boilers in each dwelling.

Small central heating plants have not been considered in detail by the Installations Committees, and a few notes may not be out of place here. In addition to the general requirements for solid-fuel appliances mentioned in the previous paragraph, small central heating boilers should have sufficient secondary heating surface, adequately scrubbed by the flue gases. The waterways should be narrow, and correctly designed to control the direction and rate of flow. For boilers used for combined heating and hot-water supply, a grate of adjustable area should be provided for summer and winter conditions. The boiler should be insulated, and provided with thermostatic or constant-draught control. Normally, graded solid smokeless fuel is employed; but if bituminous coal is to be burnt, an automatic underfeed stoker is desirable, and this would be very suitable for larger premises where a separate boiler house is available.

Radiators placed beneath the windows give a more even temperature distribution than those placed on inside walls. Low radiators have an advantage over tall ones in this respect. Some insulation should be provided behind radiators against external walls to minimize the heat loss.

Radiators should be designed for easy cleaning. The colour and type of paint used make no appreciable difference to the heat emission, so long as the paint has a non-metallic pigment.

GAS APPLIANCES

12. 1. 2. Gas appliances of all types have been the subject of a large amount of scientific investigation in the inter-war period, and improvements have been rapid. In addition to the normal gas fire, there had been marketed before the war a gas fire including some convection heating, and in view of the appreciable increase in efficiency claimed for this type, it seems reasonable to suppose that it will be developed for low-cost housing. The newer methods of control, which permit the fire to be turned low without sacrifice of radiant efficiency, should also be adopted.

ELECTRICAL APPLIANCES

12. 1. 3. Electrical appliances of all types have been highly developed. Space-heating appliances are available in a variety of types suitable for convection heating, high- or low-temperature radiant heating, and general or directional heat distribution. The electricity is converted into heat at 100 per cent efficiency, and usually all the heat is released into the room.

PREVENTION OF HEAT WASTAGE

12. 1. 4. With some heating appliances, a considerable quantity of heat is carried up the chimney by the flue gases, and the possibility of recovering this waste heat would merit attention, although, as mentioned above, some progress has been made in this direction in the design of solid-fuel and gas fires. This study would also entail reconsideration of the design of the flue.

All heating appliances should be appropriately insulated. A substantial saving of fuel will result from the use of larger amounts of insulation than have been common in the past. Thus, insulation of the back and sides of fireplaces reduces

the heat loss and increases the radiant efficiency; and when applied to multi-duty appliances, insulation helps to ensure satisfactory performance and independence of function. Removable insulation may also be of value in certain cases. For example, the hot-plate of a solid-fuel cooker may be left exposed in winter to help warm the kitchen; but in summer it should be covered when not used for cooking.

Thermostatic control is desirable from the point of view of convenience, comfort, and fuel economy; and such controls are available for use with all types of fuel. They have already found considerable use in gas and electric cookers and water heaters, in electric irons and in some space-heating equipment. In the case of space heating, the thermostat need not control within fine limits, and should be of a durable pattern.

12. 2. CHIMNEY CONSTRUCTION

12. 2. 1. The performance of any appliance in which combustion takes place is very much affected by the chimney to which it is connected. Solid-fuel appliances rely on chimney draught to pull air for combustion through the fire or boiler. The intensity of this draught depends on the height of the chimney. Draught is likely to be erratic with low chimneys, where they are particularly subject to the influence of wind. To ensure satisfaction a chimney should terminate at least 2 ft. above the ridge of the roof which it penetrates and not less than 2 ft. above the ridge of any roof within 10 ft. of it. A chimney considerably higher than necessary makes difficult the proper control of air-flow through a boiler by means of its dampers. In such cases an additional flue damper or automatic draught-regulator should be used to limit the maximum draught exerted on the boiler. Individual appliances should each have their own flue, which should preferably be on an inside wall. Adequate cleaning facilities (soot doors) should be provided and the walls of the chimney should be air-tight.

The interior surfaces of chimneys should be smooth and of fire-resisting construction; sharp bends, sudden changes of cross-section, and pockets should be avoided. The throat of a chimney connected to an open fire is particularly important and should be constructed in accordance with Fig. 2.

12. 2. 2. The combustion of almost all fuels results in the formation of some water vapour. If an appliance is efficient, the flue gases will in all probability be so cool to begin with that at some point in the flue their temperature will fall below the dew-point, and condensation of some of the water vapour will take place. The resultant moisture is of an acid nature and corrosion of the interior of the flue may ensue.

The difficulty may be met by the admission of a controlled amount of air to the flue in order to dilute the gases. Gas-burning appliances need the further precaution of a vitreous flue-lining with acid-resisting joints, and also a drain at the foot of the flue. Gas fires, which induce a considerable air-flow up the flue, do not need these precautions.

12. 3. INSTALLATION AND OPERATION

SELECTION OF APPLIANCES

12. 3. 1. There are available in each of the fuel industries a variety of types of appliance with different characteristics according to the purpose for which they were designed, and research and development may be expected to continue. In the selection of appliances it is important, therefore, that due regard should be had to the service which is required, in order to ensure that the appropriate appliance is installed. Neither bench efficiency nor even overall efficiency of heat

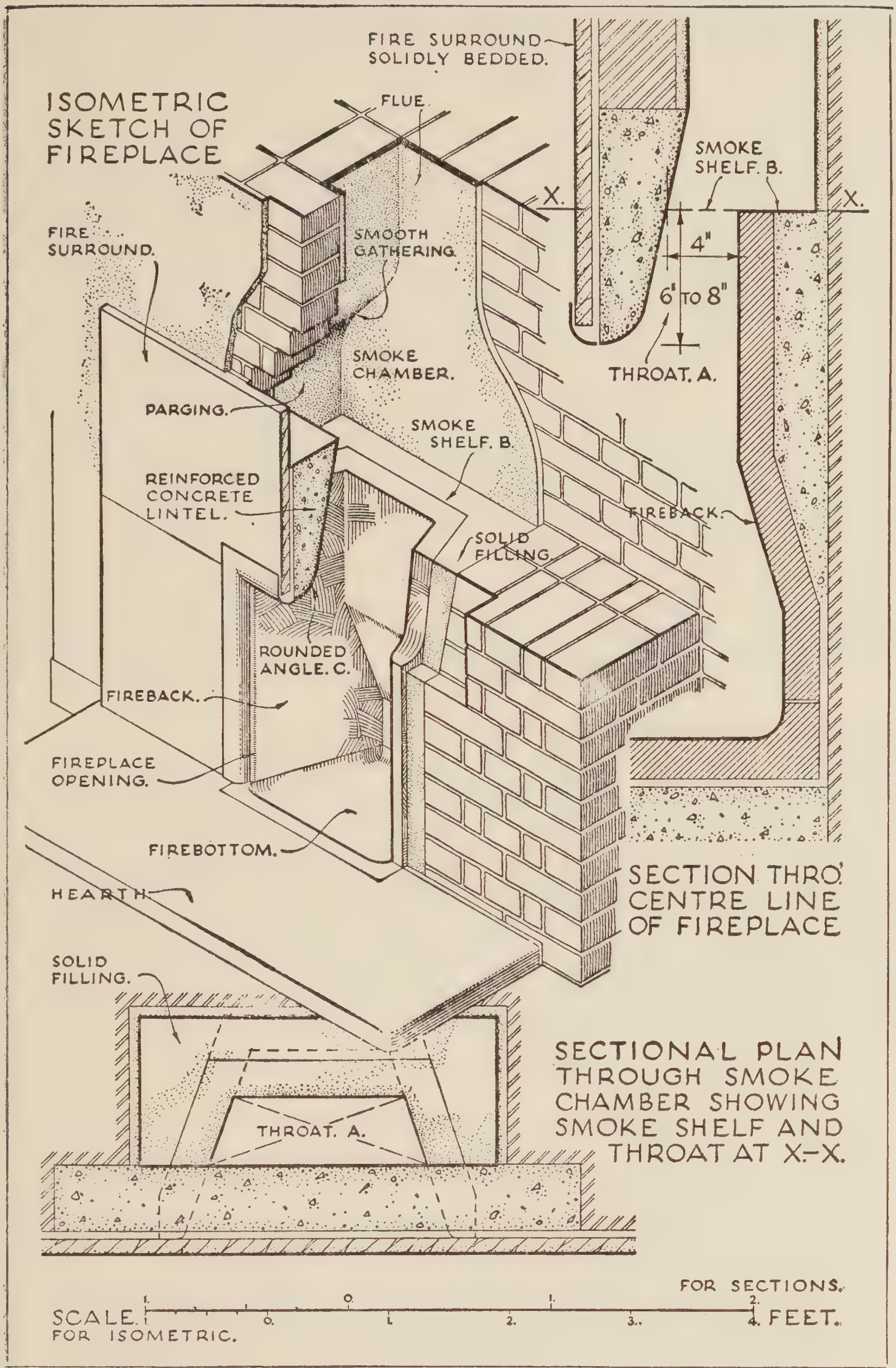

FIG. 2. RECOMMENDATIONS FOR THE DESIGN OF OPEN FIREPLACES

transfer in practice is a complete criterion. Appliances delivering identical amounts of heat into the room may provide quite different standards of comfort, according to the proportions and types of radiant and convected heat. Further, for any purpose, there are appliances of equal nominal efficiency, some to meet a greater and some a lesser or more intermittent demand. Disregard of such characteristics and purposes may cause much waste of fuel and dissatisfaction to the consumer.

INSTALLATION

12. 3. 2. It is quite possible to ruin the performance of a good appliance by poor or careless installation. Many small independent boilers, for example, are fixed without jointing material in the flue-pipe sockets and with the flue pipe itself projecting into the brick chimney. Such defects lead to erratic control of draught. Similar faults may be found in the fixing of almost any type of appliance. The position is one which can hardly be regulated by the manufacturers. It is gratifying to note that the Codes of Practice Committee is considering the proper installation of domestic room-warming, water-heating, and cooking appliances.

Many appliances can, with advantage, be fitted with certain auxiliary devices such as thermometers for ovens and boilers, and safety valves on boilers. Probably all such fittings should be incorporated in the appliance at the time of manufacture. If this is not done they should be supplied and fixed at the time of installation.

The necessity for special provision in the house for various appliances should not be overlooked. Fuelling and ash-removal tend to be dust-making operations, inconsistent with the proper atmosphere of a kitchen. By proper planning it might be possible to reduce to a minimum the trouble of such operations.

OPERATION

12. 3. 3. No appliance will give the best results with ignorant and careless attention. Too often such attention is the result of lack of instruction in the best way in which to run an appliance. Probably solid-fuel appliances, burning a fuel relatively cheap in first cost, have suffered most in this respect. The issue, by manufacturers, of booklets of instructions does not completely meet the case. They may get lost when changes of tenancy occurs. Proper use of appliances is so important in attaining economy and good results that it would be well worth the while of the appropriate industries to carry out educational work, as is already done by the gas and electricity industries.

EXISTING APPLIANCES

12. 3. 4. Although the development and selection of improved appliances for new housing schemes may be assisted by attention to principles which have been discussed in this Report, the fact remains that millions of appliances are installed in existing houses, and these will continue in use for many years. Some reference needs to be made to the ways in which they should be operated or modified so as to gain economy for both the householder and the nation. Many of the economies which have been suggested during the war are war-time economies and would not be advocated for peace-time, as they are designed to reduce the amount of heat provided and to lower the standard of heating; but some of the suggested economies are equally applicable to peace-time conditions. As instances, it has been stated that 12 to 15 per cent of the fuel used for cooking operations can be saved by due attention to certain details, and, as already discussed in this Report, great savings can often be made by suitably lagging hot-water systems.

It has been estimated that there are in potential use some 8 million open fires, 3 million combination grates (back-to-back, side-oven, or over-oven fires), 2 million ranges; and 3 million coppers.

Owing to the use of so many combination appliances, it is impossible to arrive at an accurate estimate of the total coal used for domestic cooking and water heating; but according to the best information available, this represents over 40 per cent of the total coal (including that for gas and electricity) used for domestic purposes. The importance of operating the existing appliances to the best advantage is clearly indicated.

Where the existing appliances cannot be regulated to give the lower heat-requirements in the summer months, it may be well worth while in certain cases to install an additional appliance for this purpose, in view of the saving of fuel and more comfortable conditions which would result.

A few notes on the operation of various appliances which are of general application are made here, but as pointed out elsewhere in the Report (paragraph 13. 1. 2) it would be an assistance towards the efficient operation of household appliances if instruction in the subject was provided and there was more efficient servicing of the appliances.

a. *Solid-fuel Appliances.*

i. An appliance should be of such a size that it can perform the duty required of it. A space-heating appliance, for instance, should be capable of heating the room to 65° F. even on the coldest day. Nevertheless at other times it would often be possible to economize fuel by curtailing the grate space by addition of firebricks.

ii. Flues should be kept clean.

iii. The fuel should be dry. Fuel can be saved by lighting fires efficiently and at the right times, and by correct stoking.

With open fires it is better to feed them frequently with suitable sized coal, so as to maintain as small a fire as will provide the heat at good and even efficiency, rather than to let a charge burn low and recharge at long intervals. If, however, a room is to be unoccupied for some time, fires should be banked with fines.

It is usually worth while to bank a boiler if hot water is required within 30 hours; if at longer interval, the fires should be allowed to die down and be re-lit later. Careful attention should be paid to correct boiler flow temperature. Full directions for the operation and maintenance of domestic hot-water boilers and of small hand-fired central heating boilers are given in the Technical Service Booklets which are now widely available, and there is no need to repeat the instructions given therein.

b. *Gas Appliances*

Two-thirds of the gas made is used for domestic purposes and two-thirds of this is used for cooking; the rest is about equally divided between water heating and room heating, so that it is evident that any improved efficiency is more important in relation to cooking. Much of the heat of the gas is wasted during cooking operations. The small burner should be used in all cases in which it is sufficient. Vessels should be wide-bottomed or finned and the sides polished. In using both gas and electric cookers no more liquid should be heated than is required; lids, preferably non-conducting, should be provided to the cooking pots; the oven space should be well utilized; and the stove should be kept clean and in good repair. Similarly, gas fires should be kept in good adjustment. For a small quantity of water a kettle is often more economical than a water heater.

c. *Electric Appliances*

Where solid hot-plates are used on electric cookers, much heat is lost if the base of the pot is not flat and in good contact with the hot-plate. Cooking pots should

be well polished outside, but not the bottoms, and the pots should fit the plate, whose surface should be covered. Immersion heating should be used when possible. It is more economical to boil water in an electric kettle than to heat up a boiling-plate from cold solely for this purpose. The reflectors of personal warming appliances should be kept clean and bright.

12. 4. QUALITY OF WATER SUPPLY

The quality of water is of importance in relation to water heating. Water may be acid and consequently corrosive, particularly when the catchment area is a moorland district. In chalk and limestone districts it is liable to be hard, with consequent deposition of scale when it is heated.

An acid water attacks cast-iron boilers, leading to their deterioration and also to the water having a rusty appearance. In such cases boilers may be bower-barffed, giving them a coating of acid-resisting oxide. Copper is commonly used in acid-water districts (*e.g.* Scotland and parts of England). Probably the best method of avoiding corrosion is to use the indirect system of hot-water supply with a copper cylinder and a cast-iron boiler. The pipes also should be of copper to prevent electrolytic action.

Scale formation depends on the chemical composition of the salts in the water and the temperature to which water is heated. Rapidity of water circulation hinders the adherence of scale to the boiler surfaces. Scale formation may be diminished by maintaining the boiler temperature at the lowest temperature suitable for any particular purpose. The indirect system is probably the better solution. It automatically limits the water temperature, prevents scale formation in the boiler, and also requires scale removal from the cylinder only, which is a simple process. For hard water districts galvanized steel may be used for cylinders and piping.

An alternative in either hard or acid water districts is conditioning of water at its entry to the house, but it is essential to give the apparatus frequent attention. It is felt that more attention might be paid to the possibility of treating water at the works, rather than in small quantities at consumers' premises.

CHAPTER 13

TESTING, SPECIFICATION, AND STANDARDIZATION OF HEATING APPLIANCES

13. 1. NEED FOR STANDARDS OF PERFORMANCE

13. 1. 1. Housing authorities must inevitably be placed in a position of some difficulty in deciding between the claims made for the various appliances which may be brought to their notice. It is very desirable, therefore, that means should be devised without delay for specification, testing, and certification of appliances in terms of their efficiency, so that housing authorities may have no doubt whatsoever as to the true merits of the appliances they decide to install.

13. 1. 2. Past experience has shown that, so far as solid-fuel appliances are concerned, the attention of the purchaser has usually been focussed on the appearance and on the ease of keeping clean, rather than on the efficiency and fuel consumption. In the case of gas and electric appliances, on the other hand, it has been quite customary for the public to inquire as to the running cost. This may be

due in part to the higher price of these processed fuels and to greater familiarity with the performance of solid-fuel appliances, but it is probably also due to the publicity which the gas and electricity industries have given to their considerable researches in the field of fuel economy.

The attention of the public and of housing authorities needs to be drawn to the importance of the efficiency of heating appliances, as well as to the appearance and first cost, not only in their own financial interest but also that of the wider national economy. Much could be done through housing managers or others with similar opportunities and experience. It is also essential that training should be available for those individuals and officers of local authorities who may have the responsibility of giving advice and of implementing regulations.

13. 1. 3. The problem of meeting the needs of the appliance manufacturers who will have to make improved appliances, and of the housing authorities who will have to choose and install them, falls naturally into three stages. The first stage is the clear statement and general acceptance of the requirements which need to be fulfilled. For the small house or flat this aspect is dealt with fully in Chapter 2 of this Report, and the adoption of recommended standards is the first essential. The second stage is to set up some organization for authoritative and impartial testing of newly-developed and improved appliances in order to enable manufacturers to organize their production programme as soon as the seal of approval is set on a new proposal. The last stage is to provide the necessary safeguards for the purchaser, so that he can specify appliances having the required performances with the assurance of getting an article which will be adequate. This last stage would naturally fall into the scope of the British Standards and, in fact, there are already a number of British Standards in existence covering part of the field.

13. 2. TESTING OF HEATING APPLIANCES

It has been noted in Chapter 2 (p. 14) that the evaluation of a method of room heating is a matter of some complexity, involving the control and measurement of a number of factors. A scientific test in which the various factors are controlled and accurately measured should, it is believed, become a recognized step in the marketing of an appliance. Were this measure to be generally adopted, the inferior types of appliance should soon disappear, and this would be all to the good. It should not be overlooked that in this connection the whole of the heating services of a house—space heating, cooking, and water heating—must be considered; and gas and electric appliances must be studied as well as solid-fuel appliances. The testing of grates [1] for the domestic open fire is, in fact, often inseparable from arrangements for the testing of water heaters or cookers using solid fuel, for they are often combined in one appliance. There is also the question of the design of fire-backs and of flues, for, properly speaking, the fire-back, flue and grate should be considered together as a single whole. The determination of the suitable range of sizes of appliances for a given heat requirement is also important.

The efficiency of all well-designed open fires, depending for their heating effect almost solely on the radiation emitted, has been found to lie within close limits; and it would seem undesirable to undertake a series of tests on, say, stool grates from different manufacturers. The work should proceed on the lines of testing new appliances which seem to represent a real advance in efficiency and economy. It is considered essential for future progress that there should be established means of carrying out this work of testing appliances.

[1] In the case of solid-fuel appliances it would be necessary to specify standard fuels with which to carry out the tests.

13. 3. SPECIFICATION

13. 3. 1. In the specification of heating appliances it is necessary to take account of the following factors:

a. The capacity to provide the maximum quantity of heat needed at any one time (often termed the "rating" of the appliance).

b. The efficiency of the appliance, both on the test bench and under conditions simulating domestic usage (Chapter 6).

c. The workmanship and quality of the materials used in the manufacture of the appliance, which together make for durability.

d. The safety of the appliance in respect of the emission of injurious fumes and danger from fire.

e. The efficiency of the appliance and its safety are linked with the method of installation, and a code of practice for the installation of appliances is needed to complete the scheme.

f. For many purposes, flexibility in operation has a great bearing on cost and satisfactory character of performance. Both the ease of automatic adjustment of output to demand, and the rapidity with which the full output is attained or discontinued, need to be considered. It is, therefore, necessary that there shall be tests which provide some criterion of flexibility in both these senses.

13. 3. 2. There is in existence a number of British Standards for heating appliances and apparatus used in heating. These are enumerated in Appendix 5. Most of them deal with workmanship and quality of materials, some include requirements for ratings, and some deal with safety; there are methods for testing domestic hot-water boilers, gas appliances, electric boiling-plates and gas ovens. The specifications, however, have no uniformity in scope or intent, and it would be difficult for a housing authority to make effective use of them. They are, no doubt, of much value to a heating engineer as a safeguard in points of detail. A review of the whole field embraced in heating equipment is needed, and a specification, or specifications, on a uniform basis, covering the requirements enumerated above, should be aimed at. The gaps in the list of specifications would need to be filled. The British Standards Institution is now actively engaged in drafting many of the needed standards. Research and testing, referred to in paragraph 13. 2, would have to run parallel with the preparation of the standards.

13. 4. STANDARDIZATION

The possibilities of economy in the production of heating appliances through a measure of standardization deserve some consideration. Even if the appliances as a whole were to remain as diverse as they are at present, there is the important question of dimensional standardization of parts which have to be fitted to auxiliary apparatus. Flue outlets, connections for flow and return pipes, and draw-off pipes should be standardized for size and position so that units are interchangeable. This would confer great advantages in maintenance and replacement of equipment, and would pave the way for factory assembly of piping and connections of all kinds. It is recommended that the British Standards Institution should explore the question of dimensional standardization parallel with their investigation into performance standardization.

CHAPTER 14

FUELS AND FUEL DISTRIBUTION

14. 1. CONSUMPTION OF COAL

Coal is the main source of heat in Great Britain. The uses were divided for the year 1938 as follows:

Carbonization at gasworks	19·1 million tons
Carbonization at coke ovens	19·1 " "
Electricity stations	14·9 " "
Railways	12·5 " "
Coastwise shipping	1·2 " "
"Domestic" (including anthracite), excluding miners' coal	45·8 " "
Miners' coal	4·6 " "
Other industrial uses, including coal mines	61·3 " "

The total coal raised was 227 million tons, of which about 50 million tons were exported in the form of coal, coke, or manufactured fuel, or shipped as bunkers in foreign-going vessels.

The proportion in which the total coal consumed in this country was allocated to the industrial and domestic markets is not known accurately for pre-war years, since insufficient statistics were collected. However, during the war years it has become necessary to obtain much more detailed information as to the use of coal and the derived fuels, gas and coke, and of electricity. As a result it is now possible to apply this knowledge to the pre-war statistics in order to arrive at a reasonable estimate of the extent to which coal and the derived fuels and power were utilized domestically before the war. The figures thus obtained are set out in Table 14 (1).

TABLE 14 (1)

"DOMESTIC" CONSUMPTION OF COAL, ITS DERIVED FUELS, AND ELECTRICITY

	COAL USED MILLION TONS/ANNUM	YIELD FOR "DOMESTIC" USE AS:		
		Gas millions of therms	Coke millions of tons	Electricity millions of units
As raw coal (and anthracite) supplied direct to the consumer and burnt in open fires, stoves, and boilers (including about 4·6 million tons of miners' coal)	50·4(a)			
As used in the manufacture of gas and coke, for domestic consumption	8·9(b)	925	2·5(a)	
As used in the generation of electricity for domestic consumption (excluding lighting)	4·1			5360
Total for "domestic" use	63·4(c)			

NOTES:

(a) Includes merchants' disposals to domestic consumers including disposals to shops, offices, and other establishments, partly or entirely non-residential, with an annual consumption of less than 100 tons of coal and/or coke.

(b) This figure was obtained by applying to the domestic purchases of gas and coke the

second method of determining the efficiency of the gasworks process set out on pages 59 and 60.

(c) Includes approximately ½ million tons of coal carbonized at low temperature carbonization plants—to produce approximately 0·4 million tons of low temperature coke (included in items marked (a)).

(d) The figure of 45 million tons for consumption of raw coal for domestic use given in paragraph 1 of Post-War Building Studies, No. 10, *Solid Fuel Installations*, referred to raw coal only and excluded disposals to shops, offices, etc. The estimates on which certain of the other figures given in the paragraph under reference are based, namely for coal accounted for by the household use of gas, coal, and electricity, and for the amount of coke used domestically, have since been considerably modified.

14. 2. CHARACTERISTICS OF COAL

COMPOSITION

14. 2. 1. Coal as mined in Great Britain varies widely in character and in its suitability for different uses. For the purpose of this Report it is not necessary to do more than distinguish between the more important characteristics that affect the use of coal, particularly for heating in buildings. Coals do not fall into readily definable groups with sharp demarcations in their properties: they merge gradually from one type to another, and since the different properties may vary independently, the classification of coals is a matter of considerable complexity.

Coal consists chiefly of carbon, with smaller proportions of hydrogen, oxygen, and nitrogen, but these are always associated with impurities such as mineral matter, organic sulphur, and moisture. The mineral matter appears after combustion in the form of ash, which varies from about 1 per cent in exceptionally clean coals to over 20 per cent in exceptionally poor coals. The ash content of the majority of British coal seams lies between 3 and 7 per cent. The moisture content of air-dried coal (*i.e.* coal that is free from adventitious moisture and appears dry) varies broadly with the type of coal, generally within the limits of 1 and 15 per cent.

The characteristics which are of importance when considering the suitability of coals for heating and most other purposes are, besides the calorific value, the volatile-matter content, the caking properties, the ash- and moisture-contents, the ease of ignition, and the size.

VOLATILE MATTER

14. 2. 2. The volatile matter in coal is defined as the percentage loss in weight (other than that due to moisture) when coal is heated at 925° C. under specified conditions. In British coals it ranges from about 4 per cent to 45 per cent. (All volatile-matter figures in this Chapter are calculated on a dry ash-free basis.)

The volatile-matter content affords a simple basis of classification. Bituminous coals cover the wide range of from 18 to 45 per cent of volatile matter: they constitute the bulk of British coals and are found in every coalfield, yielding about 90 per cent of the total annual output of the country. Anthracites range from about 4 per cent to 10 per cent of volatile matter; with the exception of a few small areas in Scotland, they occur only in South Wales. They form about 3 per cent of the total annual output. Coals between these ranges (*i.e.* with 10 to 18 per cent of volatile matter) have been given various names in the past, but in a recent classification issued in South Wales they have been named sub-bituminous (10 to 14 per cent) and semi-bituminous (14 to 18 per cent of volatile matter). These two classes occur principally in South Wales, but small deposits are found in Scotland and some Kent coal belongs to the semi-bituminous class. The output of sub-bituminous coal is about 3 per cent of the total, and of semi-bituminous coal about 4 per cent.

The proportion of volatile matter has an important effect on the character of combustion, which is reflected in the fact that bituminous coals are sometimes described as "long-flame" or "short-flame", according to whether their volatile-matter content is high or low. In addition, the amount of volatile matter affects

the production of smoke. Bituminous coals of high volatile-matter content give a smoky flame when burnt in an open fire, while bituminous coals of low volatile-matter content, and semi-bituminous coals, produce little smoke.

CAKING PROPERTIES

14. 2. 3. The caking properties of coal are those properties which determine the degree of coherence between the coal particles when heated out of contact with air. They are difficult to define exactly, especially as the different methods of determination usually employed give results which cannot be correlated closely with one another, but in general terms the ability of a coal to form a coherent coke can be simply expressed by stating that it is strongly-, medium- or weakly-caking, or non-caking.

Anthracites and sub-bituminous coals do not exhibit caking properties, but at about 13 to 14 per cent of volatile matter incipient caking properties appear, increasing rapidly to a maximum at between 22 and 26 per cent of volatile matter. This increase in caking power with increase in volatile matter shows a close and approximate linear relationship. As the volatile matter increases from 26 per cent, the caking properties decrease and eventually disappear, but the relationship between the two characteristics is not so close as in the lower volatile range. The generalization can be made that coals of between 26 and 30 per cent volatile matter are strongly caking, and those of between 40 and 45 per cent are non-caking, but between 30 and 40 per cent, coals of identical volatile content may differ widely in caking power.

ASH CONTENT

14. 2. 4. The percentage of incombustible residue remaining after the coal is completely burnt is termed the ash content. The ash is derived from the mineral matter originally present in the coal, but, as a result of the heating during combustion of the coal, it differs somewhat from the original mineral matter, both in amount and composition. Apart from the cost of the transport and handling of useless inert mineral matter, a high ash content in coal tends to choke or smother fires and involves extra trouble in cleaning them and in ash disposal, and it may add to fly-ash pollution. Ash having a low fusion temperature may give rise to severe clinkering trouble. In some cases, however, a certain amount of ash is desirable, since by accumulating on the fire-bars of a grate or furnace it helps to protect them from the effects of the severe heating to which they would otherwise be subjected. The amount of ash from British coals is very variable, but in general is comparatively low. The ash content of most coals can be considerably reduced by cleaning, which removes a large proportion of the shaly material brought to the surface with the coal. It is not possible, however, to remove the ash-forming constituents that are finely disseminated through the body of the coal itself, so that cleaning can never eliminate the ash entirely. A good, clean, sized coal has commonly an ash content of 2 to 4 per cent, and occasionally even lower.

MOISTURE CONTENT

14. 2. 5. The moisture content of coal can be considered as consisting of two parts: (a) the inherent or natural moisture, determined after thoroughly drying the coal in air at atmospheric temperature, and (b) the free moisture, sometimes regarded as surface moisture, due to any water brought up with the coal as mined, to the method of preparation of the coal (*e.g.* wet cleaning processes), or to the exposure of the coal to wet weather during storage or transport. The inherent moisture and the free moisture together give the total moisture, often termed "moisture as received."

The inherent or air-dried moisture shows a broad relationship with the type of coal. The maximum value (12 to 15 per cent) is found in the high-volatile bituminous weakly-caking coals, and the amount falls with decreasing volatile-matter content until a minimum of about 1 per cent is reached in the semi-bituminous

and sub-bituminous groups, rising again to between 1 and 3 per cent in the anthracites.

The amount of inherent or air-dried moisture, being characteristic of the type of coal, has to be accepted as an integral part of the coal purchased. A high free-moisture content, however, is generally undesirable, as it causes a double loss to the purchaser; like ash, it has to be bought, transported, and handled, and loss of heat occurs during burning owing firstly to the heat required to vaporize it, and secondly to the loss of sensible heat carried away by the vapour so formed. In the larger-sized grades used for domestic heating the amount of free moisture is usually low, but it may reach a high figure in the smaller grades and slacks.

IGNITABILITY

14. 2. 6. The ignitability of coals is of particular importance in coals used for domestic heating by intermittent methods. In general, the higher the volatile matter the easier the coals are to ignite. Coals with low volatile matter, such as anthracites, are usually more difficult to ignite, but in continuous-burning appliances, such as stoves and hot-water boilers where relighting is infrequent, this disability is more than offset by the advantages of using low-volatile coals.

SIZE

14. 2. 7. The size of coal as marketed is a very important factor in determining its suitability for various purposes. The coal as brought up from the pit consists of pieces of all sizes from fine dust to large lumps two or three feet in length. This material is passed over screens with various sized apertures, which thus separate the large from the small. The larger coal, roughly that over 3 in. in size, is passed along picking belts where the recognizable pieces of "dirt" are picked off by hand. The larger pieces of coal may also be selected by hand for separate marketing. The smaller coal (below 3 in. in size) may then go to the washery or dry-cleaning plant, but whether or not it is cleaned, it is generally again screened to provide various sizes of coal for industrial use. Coal is sold in three broad classes:

a. Large coal, including hand-selected.
b. Sized or graded coal.
c. Slacks.

Sized coals are those which have been screened between two sizes of sieve and from which in consequence the fines have been removed.

Slacks, which are known in various districts by such names as dross, smalls, duff, gum, etc., contain all the fine coal, and tend to have high ash contents. They are usually designated by the upper limit of particle size (*i.e.* the aperture size of the screen through which they have passed)—viz. 1-in. slack, ½-in. slack, etc.

There has been in the past no uniform practice in the screening and grading of coals in the different coalfields, and there is little reliable data on the relationship between the sizes and the combustion properties of the various coals. It is well known, however, that there are different optimum sizes for burning different coals in particular types of plant or appliance. The large lump, which has hitherto been a feature of the domestic market, has little to commend it and certainly does not justify the high price often demanded. The present trend is towards more complete coal cleaning and the supply of coal in fewer but standard sizes, a practice to be recommended.

OCCURRENCE OF DIFFERENT TYPES

14. 2. 8. The Coal Survey Section of the Fuel Research organization (Department of Scientific and Industrial Research) has for many years been engaged upon a systematic study of the occurrence and properties of coals from all the coalfields in the country. The distribution of the various types of coal is summarized in Appendix 6.

14. 3. TYPES OF COAL FOR VARIOUS PURPOSES

From the point of view of the heating of buildings, the main uses of coal are:

a. Burning in coal-fired appliances in the home.

b. Carbonization to make gas and coke.

c. Generation of electricity.

and the types of coal most suitable for these purposes will be broadly indicated.

DOMESTIC USE

14. 3. 1. For open fires, with or without back boilers, bituminous coal with a volatile-matter content of over 30 per cent is most commonly used. The types preferred are those having non-caking or moderate-caking characteristics, and low ash contents. Coals having lower volatile contents are, however, used satisfactorily, and produce less smoke.

The size of fuel most suitable for open grates varies with the type of fuel and the design of grate. Large coal which is not too friable burns well in hearth-bottom grates, and it is also satisfactory for normal stool-bottom grates in which the draught control is usually not very effective. Where more rigid air control to the grate is provided, smaller grades of coal of the order of 1 in. to 5 in. may be used with advantage. Suitable sizes for anthracite and coke are approximately 1 in. to 3 in. and 1 in. to 2 in. respectively.

For heating stoves of the openable type, coals of less than about 13 per cent volatile-matter content are to be preferred, since coals of high volatile-matter content may cause excessive deposition of tarry matter and soot in the stove and flue. Anthracites, sub-bituminous coals, and some briquettes and manufactured fuels are suitable, and gas coke may also be burned if the size of the stove is sufficient to give overnight burning, about 0·6 cu. ft. being required for this purpose. Briquetted fuel of low volatile-matter content and of moderately low ash content is a satisfactory fuel owing to its high density, freedom from clinker, and the fine nature of its ash, which facilitates its removal by the grate mechanism; it usually suffers from the defect, however, of presenting an ash-covered surface when the stove is used as an open fire. The sizes of fuel required are within the range of approximately 1 in. to 2½ in.

For closed stoves of the magazine-feed type, the same types of fuel are suitable as for the openable heating stove, except that all bituminous and caking coals should be excluded, and the fuel should be more closely sized so as to avoid trouble due to the bridging of the fuel in the magazine feed.

Kitchen ranges and combination grates usually require a high-volatile coal to ensure satisfactory oven-heating, a non-caking or weakly-caking type of coal of 1 in. to 2½ in. being most suitable. Few of these units can be operated satisfactorily with low-volatile fuels such as anthracite or coke, but developments are tending towards the increased use of these fuels.

Certain modern cookers are now designed to be continuous burning. These require carefully graded fuels; non-caking or weakly-caking low-volatile coals (*i.e.* anthracites and sub-bituminous coals), coke, or briquetted fuels are used, but the maker's recommendations should be followed in the choice of fuel.

As with heating stoves, bituminous coals and strongly-caking coals of the semi-bituminous class should not be used in domestic hot-water boilers owing to the lower thermal efficiency obtained, and to the deposits of tarry matter and soot that collect on the boiler heating surfaces and in the flue. Suitable fuels are anthracite, sub-bituminous coals, weakly-caking coals of the semi-bituminous class, coke, and some briquetted fuels—*i.e.* all fuels of low volatile-matter content.

GASWORKS

14. 3. 2. Gas can be and is produced from a wide variety of fuels including coal, lignite, wood, and oil, but in this country town gas is normally made by the carbonization of medium- or strongly-caking bituminous coal of fairly high volatile content, supplemented sometimes by a gas made from coke and from the cracking of petroleum oils. While these coals cover a fairly wide range, a much wider range may be made available to the industry by changes in the method of operation or in the design of the gas-making plant, and developmental work at present being carried out by the gas industry is directed to this end.

If a coal is used differing substantially from that for which the plant was designed or is adjusted, there may be difficulties in manufacturing, and particularly in maintaining the declared calorific value. A gas undertaking may be permitted to change its declared calorific value, however, and if the change in the coal is a long term one, such a step should be taken. This means that the extension of the practice of converting coal to gas is not necessarily limited by the reserves of coal of a particular type, though the cost of gas production may increase as the type of coal departs from the optimum. Of the total quantity of coal raised in Great Britain, the quantity suitable for carbonization by present methods and technique is about double that actually carbonized. If it were practicable to divert this additional quantity of gas-making coals to gasworks, the output of gas could be doubled if additional gas is required. By drawing upon the wider range of coals that could be carbonized by present methods, though with perhaps modified technique, an even larger increase in the output of gas would probably be possible.

COKE OVENS

14. 3. 3. For the production of metallurgical coke, needed mainly by the iron and steel industries, a coal that will produce a mechanically strong or "hard" coke is required. For any particular design of coke oven the range of coals that can be accommodated may be limited, but in the last two decades it has been demonstrated in industrial practice that by suitable selection of the oven width, and by blending coals of different caking properties, a wide range of coals can be made available for the production of metallurgical coke. It is desirable that the sulphur- and phosphorus-content of the coke should be low, and though coal cleaning prior to carbonization helps materially in this respect, this limitation excludes a number of otherwise suitable coals.

Any excess of metallurgical coke above that required by the iron and steel industry is diverted to other markets, and is often used as a fuel for boiler plants heating larger buildings.

The carbonizing industries (gasworks, coke ovens, and low-temperature carbonization plants) are responsible not only for the production of gas and coke but also for numerous secondary products. These include road-tar, creosote, pitch, benzole, naphthas, tar acids and bases, naphthalene, cyanides, and ammonium sulphate. Some of these form the raw material for many branches of the chemical industry, others are used as fuel for specialized purposes, and still others are used for road surfacing and other constructional work.

ELECTRICITY GENERATION

14. 3. 4. For electricity generation the range of coals which may be used is very wide. The majority of electricity generating stations can burn fuels which many other users find difficult to employ, and this is all to the good since it provides a market for the poorer material such as high-ash slacks, thus helping to utilize the whole coal resources of the nation. Modern power-station boilers are designed and maintained by highly competent fuel technicians, and can be designed to burn efficiently almost any fuel that is obtainable. The design of any given plant, however, largely determines on technical and economic grounds the type of fuel

which can be used in that plant, and it is therefore necessary that generating stations should be assured of a continuous supply of the type of fuel for which their boilers are designed.

14. 4. DISTRIBUTION OF FUEL AND ENERGY

COAL

14. 4. 1. The cost of distribution of coal from railway to consumer appears unduly high, being often not greatly less than the cost of production. The Committee has made no exhaustive inquiry into this aspect, but it is probable that the distribution costs remain high, firstly, because the business is in the hands of a great diversity of small retailers, each with its own establishment charges, and secondly, that the frequent delivery of coal in small lots involves heavy handling charges. This is particularly the case where deliveries have to be manhandled to the upper floors of blocks of flats.

The remedy for the first of these disabilities may possibly lie in joint action between the firms handling the retail trade and the collieries to eliminate inefficiency. It is also desirable to foster in the coal retail trade the principle of service to the consumer in the way of advice on choice of fuel and appliances, on a par with that already established with gas, smokeless fuels, and electricity.

The organization of the distribution of coal is a question which should have its place in any national plan relating to the fuel industries.

As regards the problem of distribution of coal in small lots at frequent intervals, the importance of providing in new buildings storage accommodation for delivery of fuel in reasonable bulk has been stressed. A figure of three months' supply for normal winter usage has been suggested as the minimum storage space which should be contemplated. The saving in the cost of delivery in larger lots has to be balanced against the cost of the storage space in the building. The problem of the delivery of solid fuel to the upper floors of blocks of flats is a serious one, and it would seem almost essential that in flats where solid fuels are burnt a service lift or hoist should be provided. It has been stated that facilities are available in some districts for payment in weekly instalments for bulk deliveries of coal, so that the low-income groups should be able to profit from the advantages of larger fuel storage space. For the heating plant for larger buildings it is very desirable that the fuel store should be so contrived that bulk delivery from tipping waggons is always possible, provided it can be assured that, in return, the consumer is given the advantage of the saving in handling costs. Care should be taken to avoid the creation of a dust nuisance.

The Heating of Dwellings Inquiry shows that monetary outlay is one of the main factors in deterring low-income groups from taking fuel in bulk, and that the majority buy 3 cwt. or less at one time. None the less there is reason to suppose that a large proportion of the population would be unable to take supplies in bulk of over 5 cwt. on account of restricted storage space.

The persistence of the sale of coal in large lumps for the domestic market has been referred to. This appears to be a survival from earlier days, and a practice which might well be allowed to lapse: it is uneconomical, often involving the hand-packing of railway waggons at the colliery, and the large lump does not conduce to efficient burning by the consumer; when the lumps are broken there is a considerable amount of slack produced in the consumer's coal store, and the disposal of this is sometimes difficult. The question of the control of quality of solid fuels delivered to the domestic market is exercising the minds of various sections of the industry. Sales by declaration of calorific value have been suggested as one method of control, but it has been pointed out that this would not be entirely satisfactory since the utility of a coal to the householder depends very largely on its burning qualities, and the calorific value is not necessarily an index of these. The general

conclusion reached at the present stage of the inquiry is that the sizing and cleaning of coal is probably the most satisfactory development to pursue for the domestic market. This might well be accompanied by some simple forms of quality specification and a limitation in the large number of sizes at present marketed.

So far as heating of buildings is concerned, there are two important factors to be considered which arise from the variable nature of the coals. An appliance which works well with one type of coal may not be by any means so efficient with a coal of an entirely different type. Consequently, it is necessary to consider details of the design and installation of appliances regionally in order to take into account the nature of the local fuel supplies. It is doubtful, for instance, whether it would be possible to standardize an appliance for nation-wide use unless it were capable of using a very wide range of fuels. This, however, should not be taken as invalidating the broad general principles underlying the efficient use of fuel for heating; and it certainly should not be made an argument for continuing to burn a local fuel in a grossly inefficient appliance, with a maximum of smoke emission, merely because it happens to be the present custom to do so. The other factor which must not be lost sight of is that a particular coal in a particular appliance may represent an extremely efficient combination, even perhaps to the extent of being far superior to any other, but it would be unwise on that account to advocate its use to the exclusion of everything else in all circumstances. The particular fuel may only be available in a few localities, and the total output may be insufficient to allow it to be used on a nation-wide scale to the exclusion of others.

COKE

14. 4. 2. The main development in the domestic use of gas coke has been in London and the Home Counties. The sales in this area have increased very largely due to the maintenance of improved standards of quality in the fuel and to the development of suitable grates for burning it. There is, therefore, in existence a system of service to the consumer in the retailing of coke, which was referred to as a possibility for coal in paragraph 14. 4. 1. The domestic use of coke has not developed in other parts of the country to the extent which it has in the London area, despite the fact that the relative prices of coal and coke are said to be the same in these other areas.

A step in the direction of rational marketing of coke has already been taken by the industry. Coke in the London area is crushed and graded and the number of sizes has been reduced to five, which appear to meet all requirements. It is understood that a nation-wide extension of this rationalization is on the way. As in the case of coal, the consumer should be safeguarded in regard to the quality of the coke delivered. The desirable qualities of coke for domestic use are low ash- and moisture-contents, and a reasonable proportion of volatile matter left in the coke. These qualities, particularly the last, contribute to its combustibility and ease of ignition. Further, in order to minimize nuisance in handling, the coke should not be dusty.

LOW-TEMPERATURE COKE

14. 4. 3. Low-temperature coke is subject to high distribution costs from rail to consumer. It is handled by the same class of retailer as coal, and the high cost of distribution is in part due to the causes indicated in paragraph 14. 4. 1. An interesting development in the sale of this fuel is marketing in very small lots in paper bags, and this type of sale is stated to have increased very rapidly. It would seem that the convenience and cleanliness of this method, and the small outlay needed for the very small lot, has made it attractive to some consumers, but it is clearly an expensive way of purchasing fuel. At present, however, it is adopted in deference to a well marked demand.

GAS AND ELECTRICITY

14. 4. 4. The gas undertakings are under statutory obligation to maintain a declared quality of the gas; and the electricity authorities are required to maintain the voltage within definite limits, and heat or energy can therefore be purchased by simple metering. This is an advantage not to be lost sight of in the wider use of these services.

LOAD FACTOR

14. 4. 5. A large proportion of the total costs of production and distribution of coal vary directly with the consumption, and the price to the consumer is, therefore, unlikely to be appreciably reduced with increased consumption.

The reverse is true with gas and electricity. The so-called "fixed" costs (that is, capital charges, management, rates, etc.) are a high proportion of the total costs. Considerable capital expenditure has been incurred by both industries in production and distribution equipment, and the price to the consumer per therm or per unit must, therefore, depend to a considerable extent on the degree to which use is made of these capital assets. To the extent to which surplus capacity is available, increased consumption is advantageous whenever it occurs. It is also clear that the more consumers use gas and electricity for cooking and water heating and other purposes, so far as they create an even demand throughout the year, the lower will the average price of gas and electricity become.

Factors which govern the probable trend of consumption of coal, gas, and electricity, and the effect which the various types of demand have on the costs of supply, present a very complex problem, and one which does not fall within the scope of this Report.

14. 5. OTHER FUELS

Nothing has been said about the use of oil, buta- or calor-gas, wood, and peat as fuels for house heating. Although these have importance particularly in rural districts, the total quantity of heat supplied by such fuels in this country is, relatively to the other fuels, so small that they can be neglected in this general discussion. (See, however, Chapter 10 and Appendix 8.)

14. 6. BALANCE BETWEEN DIFFERENT FUELS

14. 6. 1. Local prosperity in any given area will depend to some extent upon the various undertakings connected with the supply of fuel and energy working under favourable conditions of load, and on the right use of the resources—coal mines, electricity and gas supply systems—available in that area. For example, at present the manufacture of gas is accompanied by the production of coke, and it might be injudicious, therefore, to aim at "all-gas" or "all-coke" heating with the resulting unbalance in supply. And although it is possible to make up deficiences by "importing" coal, coke, and electricity (and in some areas gas also), or to dispose of a surplus, this brings in the problem of distribution and transport. It would, however, clearly be extravagant to provide every possible source of heat in every house, if it would entail high capital cost for the installation and auxiliary building work which would make the heating unnecessarily expensive.

14. 6. 2. The use of fuel for the heating of domestic buildings is a matter of great national importance—nearly one-third of the country's home consumption of coal being used for this purpose directly or indirectly. From the national point of view, therefore, as well as in the interests of the householder, it is most important that there should be the maximum efficiency in the domestic use of fuel. The efficient use of coal is dependent not only on the manner in which

it is burnt, but on its treatment, its distribution, and its allocation to purposes most suited to its type. Smoke abatement as a national objective is also highly desirable.

We are glad to know that these general national issues have been referred by the Minister of Fuel and Power to the newly appointed Fuel and Power Advisory Council, under the chairmanship of Sir Ernest Simon.

A. C. Egerton, *Chairman.*
E. D. Simon, *Vice-Chairman.*
Irene T. Barclay.
J. G. Bennett.
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C. L. Scott.
W. M. Selvey.
E. W. Smith.
J. W. J. Townley
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APPENDIX I

HEATING OF DWELLINGS INQUIRY

By Dennis Chapman assisted by Geoffrey Thomas
An Inquiry by the Wartime Social Survey

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PART I. TEXT

A 1. 0. INTRODUCTION

A 1. 0. 1. This inquiry into the heating of working-class dwellings has been prepared at the request of the Department of Scientific and Industrial Research for the report on the heating and ventilation of post-war buildings undertaken by the Department for the Ministry of Works. The questionnaire was formulated in consultation with the Departmental Group mentioned in the preamble to the main Report.

The work in connection with domestic buildings called for information of a kind which could be obtained only by direct investigation in the field.

Some of the factors involved are objective sociological ones, such as household income, family size, and the relations of these factors to expenditure on heating, water heating, and cooking, to current methods of cooking, space heating and water heating, and to present habits in such matters as coal buying and laundry.

There are also a number of subjective factors that are of importance : it is necessary to know, not only the method of cooking, but also to know the housewife's beliefs about her cooking methods. It is also important to know her likes and dislikes on the subject of central heating and relate all these beliefs to her experience, because although it may be possible to work out an ideal scheme on the drawing board, it may be necessary to undertake a considerable programme of education before such an ideal scheme is acceptable. In preparing this a knowledge of existing beliefs is important.

These studies are complicated by the fact that there are regional differences : these are of two kinds. First there are the differences enforced by climatic conditions ; to take account of these the sample has been arranged into main areas on a degree-day basis. Some of the factors concerned, however, particularly cooking habits, are related to regional differences on a geographical basis. To take account of this, certain separate analyses are made on a geographical as well as a degree-day basis, because any theoretically ideal scheme may have to be modified considerably if it is to prove acceptable to housewives in different regions.

The size of the questionnaire was thus very large ; for this reason in many cases certain questions were not answered by some or other of the housewives interviewed. In no case did this reduce the sample enough to make the general conclusions at all doubtful.

The inquiry was made in February and March 1942 and therefore relates only to appliances in existence at that time.

RECEPTION

A 1. 0. 2. The reception of the survey in the 5260 households was, in general, very favourable. There were no serious difficulties in any district.

In very many cases the housewife considered herself fortunate to be able to express her views on housing in relation to post-war planning. On these occasions there were usually very many suggestions relating to other subjects besides the heating. For example, the planning and arrangement of the house, and such details as the following : the size of coal accommodation, cupboard accommodation, corners and floor angles, tiling of sculleries and kitchens, lavatory accommodation, and in a very large number of cases lack of bathroom was referred to.

THE REPORT

A 1. 0. 3. At the suggestion of the Department of Scientific and Industrial Research it was decided to make a continuous narrative giving the main facts, and to add to it at the end a set of the relevant Tables to which reference is made in the text.

The general form of the Report and the material included in it has been discussed with the Department and they have agreed, in many cases, to the omission of detailed analyses which were not particularly illuminating or whose results could be easily summarized in a few sentences.

The Report proper has the following main sections :

1. Sample.
2. Expenditure on Lighting, Heating, and Water Heating.
3. Cooking.
4. Space Heating.
5. Central Heating.
6. Hot Water and Laundry.

ACKNOWLEDGEMENTS

A 1. 0. 4. We should like to acknowledge the very considerable co-operation given to us by a very large section of the public and also the help we received from the late Mr. Stephen Lacey of the British Gas Federation, and Mr. A. C. Cramb and Mr. J. I. Bernard of the British Electrical Development Association, Incorporated.

The section on Expenditure could not have been completed had we not had the very valuable assistance of a large number of electric and gas supply undertakings. Very many of these not only supplied us with the detailed information that we asked for, but also gave us supplementary information which was most useful, and offered to answer other questions relevant to our problems.

A 1. 1. SAMPLE

A 1. 1. 1. The sample was originally designed to meet the wishes of the Department of Scientific and Industrial Research for analysis by geographical regions, by income in two groups and by family size in two groups. It was based upon the assumption that the minimum number of interviews likely to be significant in any of these groups in any region was 100. The distribution of interviews was decided in relation to the Ministry of Food returns of population figures, and within each of the Ministry's main regions the principal urban centres were represented, roughly in proportion to the population, with a minimum of 20 in any one town. It was thought that in this way each of the geographical regions would be adequately represented.

The method of choosing the sample within each town was as follows : a list of the streets in which it was believed that families in the chosen income groups lived was prepared in consultation with the local authority—usually the Rating Officer—and the quota for the town selected at random from these streets.

After the field work had been completed, however, it was decided that the regional analyses should be made on the basis of a degree-day chart,[1] which was thought to give a more precise indication of climatic differences than regions chosen merely as northern, southern, or western. Since the degree-day regions agree only roughly with geographical regions, this has resulted in a somewhat unequal distribution of interviews between the four degree-day regions finally chosen. Where local differences rather than temperature differences were considered to be important, however, geographical regions also have been used.

The rural sample has also been affected by this change. It was originally decided to use it only for the two geographical regions, Scotland and the North, and Southern England. By the degree-day system it is now scattered through each degree-day region roughly in proportion to the rural population of the country as a whole.

The sample with these revisions has three principal divisions, urban, rural, and urban flats. The latter is a special sample of flats taken in London, Liverpool, Leeds, and Glasgow in order to be certain that the number of flats represented in the sample, as a whole, would be sufficient to allow of comparisons in expenditure to be made with houses.

[1] See Glossary.

SAMPLE, REGIONALLY AND NATIONALLY

A 1. 1. 2. *Degree-Day Regions*

I. 5000–5500 degree-days	152
II. 4500–5000 „	1405
III. 4000–4500 „	1856
IV. Under 4000 „	1847
Total	5260

Geographical Regions

Scotland	757
North	1635
Midlands	742
London and South	1369
South-West and Wales	764
Total	5267

URBAN AND RURAL

A 1. 1. 3. The rural calls were made round selected market towns in Scotland and the north of England and across southern England and south-west. The numbers of rural and urban interviews are as follows:

Urban	4468
Rural	764
	5232

A list of towns for all these interviews, with an indication where rural calls have been made, is given in Part III of this Appendix.

URBAN FLATS

A 1. 1. 4. These have been taken in four towns in the following numbers:

London	100
Liverpool	97
Leeds	100
Glasgow	100
	397

In the analyses this sample has been added to the flats already found in the sample taken at random. The total of flats is, therefore, 1064.

INCOME GROUPS

A 1. 1. 5. All the interviews have been taken from two income groups only, chosen by the Department of Scientific and Industrial Research, namely, below £160 per annum family income and £160–£300 per annum family income. It must be noted that the inquiry is thus concerned with the lower paid section of the working class. The respective numbers are:

i. Below £160	2390
ii. £160–£300	2849
iii. Not answered	20
	5259

FAMILY SIZE

A 1. 1. 6. The Department required division of the sample into family groups of 1–3 and 4–7. The numbers are :

i.	Family size	1–3	2659
ii.	„	4–7	2419
iii.	„	7 and over	169
		Total	5247

CONCLUSION

A 1. 1. 7. All the Tables are based upon these figures, but in several cases where housewives have for one reason or another not answered a question the total figures for these questions will be considerably lower than the total given above. Where expenditure is concerned the total figure used is only two-thirds of the above owing to difficulties in obtaining complete details of expenditure on gas and electricity.

A 1. 2. EXPENDITURE ON LIGHTING, HEATING, WATER HEATING, AND COOKING

A 1. 2. 1. In order that any plans for the supply of space heating, water heating, and cooking may be worked out, it is desirable to know the cost of these services in present dwellings of known size and to relate these costs with family income and other factors. This result can later be referred to housewives' estimates of what they would be prepared to pay for these services if supplied from a central source.

The objective information about house size, income level, and family size was collected in the classification section of the questionnaire. The expenditure was arrived at in answer to Question 1. The annual expenditure was calculated in two ways : in the first instance, the housewife was asked what she had spent in a winter week on coal, coke, coalite, etc., paraffin, firewood, and fire lighters. This was to be the average of the last four weeks, which would have been between the first week in February and the third week in March. In order to take account of the possible local climatic variation, a note was made of the weather on every day during which interviews were made, and in all cases the weather was consistently cold, so that this result was not complicated by any local peculiarity.

In order to get the yearly figure this winter week figure was multiplied by a conversion factor worked out by the Department of Scientific and Industrial Research.

Annual expenditure on gas and electricity was obtained from the Public Utility Companies, and these figures were used in preference to those obtained from the housewives.

It was not possible to exclude lighting costs, and in all the data on expenditure lighting is included in the total " heating " costs.

TOTAL EXPENDITURE ON FUEL AND LIGHT

A 1. 2. 2. The first analyses are concerned with total annual expenditure on all forms of heating, water heating, cooking, and lighting. The separate figures for each item are not given as these were not required by the Department of Scientific and Industrial Research.

The expenditures have been prepared separately for houses and flats as it was desired to know whether or not, if owing to the better conservation of heat in large dwellings, there was a smaller expenditure in flats.

Total annual expenditure was obtained for 2561 families living in houses and for 711 families living in flats (Table 1). The average annual expenditure for families occupying houses was £16, 16*s.* 10*d.*, whilst the average annual expenditure for families occupying flats was £18, 2*s.* 8*d.*, thus showing that the expenditure in flats was higher than the expenditure in houses. We believe, from other information of a non-statistical character obtained in the course of the Survey, that this is due to the fact that in most cases the standard of heating and lighting in flats is higher than that of houses, so that although one would have expected the heating needs to

have been less, this is offset by the other factor. In addition to this it emerged that where all rooms are on one floor more of the dwelling may be used and heated, whereas in the case of the house the clear division made by the stairs effectively limits the use of the upstair rooms. This is borne out in the results of the space heating section.

In one case, however, it appears that this factor of the higher standard in the more modern dwelling does not apply, that is in the case of degree-day Region II which includes the tenements of Edinburgh, Dundee, Perth, Aberdeen, and other Scottish towns ; Region III, however, which includes Glasgow and also a considerable sample of flats in England, showed the same trend as the total.

This same point about the higher standard of heating in more modern dwellings is reflected in the comparison between old and new dwellings. The average annual expenditure of 1138 new dwellings was £18, 2*s.* 0*d.*, whereas the average annual expenditure of 2266 old dwellings was £16, 12*s.* 8*d.*

The higher expenditure in flats is reflected in almost every case of the detailed analysis given, by number of rooms in Table 1. The range in the case of houses from 1–6 rooms was from £12, 9*s.* 4*d.* to £18, 9*s.* 7*d.*, whereas the range in the case of flats was from £15, 10*s.* 5*d.* to £23, 3*s.* 2*d.*

A similar picture is given where the expenditure is analysed by number in family. This is given in detail in Table 2, where it will be seen that the range for families of 1–8 living in houses is from £11, 17*s.* 0*d.* to £22, 3*s.* 6*d.*, whereas the range for families in flats is from £12, 8*s.* 6*d.* to £22, 15*s.* 2*d.* The summary Table 3 shows the position more clearly. These broad conclusions must be modified, however, by reference to difference of annual income.

A 1. 2. 2. 1. *Expenditure Analysed by Degree-Day Region*

The average annual expenditure of households was approximately the same in each degree-day region, this being particularly true for families occupying houses (Table 4). This fact may in some measure be accounted for by the lower prices of coal in the North of England and in the more populous parts of Scotland, since the same expenditure would buy more fuel. There were some differences in the expenditure of flat dwellers, and this did not follow the degree-day region order but reflected the fact that in degree-day Region II the flats were largely of a poor working-class or tenement character.

A COMPARISON OF THE EXPENDITURE BY HOUSES AND FLATS OF EQUAL SIZE WITH EQUAL NUMBERS IN FAMILY HAVING AN INCOME OF BELOW £160 P.A. AND ABOVE £160 P.A.

A 1. 2. 3. This further analysis confirms the general impression already gained from the previous Tables, that the average annual expenditure in flats is greater than that in houses.

It will be seen from the analysis of families with an income under £160 per annum that, to take an example of families with four in the household, and with two habitable rooms, flat dwellers have an annual average expenditure of £17, 7*s.* 7*d.* compared with £14, 16*s.* 5*d.* of the house dwellers (Tables 5 A and 5 C). Those occupying flats of four rooms have an annual average expenditure of £17, 19*s.* 4*d.* as compared with an annual average expenditure of £16, 16*s.* 9*d.* for four-room houses. It will be seen that in almost all cases where the totals are large enough to be useful this difference is present.

If the total of all families of equal size is taken it will be seen that there is a higher expenditure in almost all cases of flat dwelling families ; for example, families of one £12, 5*s.* 5*d.* against £11, 16*s.* 5*d.*, families of two £15, 3*s.* 11*d.* against £13, 11*s.* 1*d.*, families of three £17, 9*s.* 0*d.* against £15, 14*s.* 1*d.*, families of four £19, 5*s.* 3*d.* against £16, 10*s.* 4*d.*, families of five £20, 3*s.* 5*d.* against £17, 7*s.* 0*d.* In the case of families of six the dwellers in houses spend slightly more, but the sample of flat dwellers in this case is rather small.

The average annual expenditure for families with an income of between £160 and £300 per annum shows broadly the same pattern. There are, however, some inconsistencies ; for example, if one compares flats and houses with two in the family, the average expenditure in houses is a little greater than that in flats, £15, 0*s.* 11*d.* compared with £14, 9*s.* 1*d.* (Tables 5 B and 5 D). With three in the family, however, the flat expenditure is £17, 15*s.* 10*d.* compared with £16, 17*s.* 0*d.*,

and similarly with four in the family £18, 9*s.* 0*d.* compared with £18, 3*s.* 10*d.* The expenditures of families of five show an even larger difference, an expenditure of £20, 12*s.* 4*d.* in flats compared with £18, 13*s.* 10*d.* in houses.

The influence of family income on average annual expenditure is very evident in the case of families living in houses, but is less clear in the case of families living in flats.

The average annual expenditure for families of 2, 3, 4, and 5 are given as an example.

	LIVING IN HOUSES		LIVING IN FLATS	
	Income under £160 per annum	Income over £160 per annum	Income under £160 per annum	Income over £160 per annum
Families of 2	£13 11 1	£15 0 11	£15 3 11	£14 9 1
„ 3	£15 14 1	£16 17 0	£17 9 0	£17 15 10
„ 4	£16 10 4	£18 3 10	£19 5 3	£18 9 0
„ 5	£17 7 0	£18 13 10	£20 3 5	£20 12 4

If a comparison is made between families of equal size occupying houses with the same number of habitable rooms, it will be seen that families with the higher income have a higher expenditure in almost every case, as, for example, in the cases of families with houses of three rooms.

	INCOME UNDER £160 PER ANNUM	INCOME OVER £160 PER ANNUM
Families of 2	£13 10 9	£14 1 0
„ 3	£14 6 10	£16 6 1
„ 4	£16 4 4	£18 13 10
„ 5	£17 5 10	£17 10 1

In the case of flats there is no such clear pattern, the expenditures often being higher in the lower income groups. The samples in these analyses are, however, very small.

AVERAGE EXPENDITURE PER HEAD ON FUEL AND LIGHT

A 1. 2. 4. The average annual expenditure per head varied with family size as follows :

	HOUSES	FLATS
1 in Family	£11 17 0	£12 8 6
2 „	£7 1 5	£7 9 7
3 „	£5 8 8	£5 17 8
4 „	£4 7 7	£4 13 6
5 „	£3 12 9	£4 1 9
6 „	£3 4 11	£3 9 1
7 „	£2 16 1	£3 8 0

The average annual expenditure of all persons was £4, 15*s.* 3*d.* per annum.

COAL CLUBS

A 1. 2. 5. The Department of Scientific and Industrial Research were interested to know how far the custom of purchasing coal through a coal club was general. This was of special interest to them as it represented a case where the purchasing of heat was done by a regularly weekly payment all the year round. This is in some ways parallel to the gas and electric charge and to the sort of charge which might be made for district heating. The questionnaire asked the direct question " Do you belong to a coal club ? " This has been analysed by the income, by region,

and by urban and rural. There were 4971 answers to this question. Of this total there were 322 coal club members (6 per cent) and 4649 who do not belong to coal clubs (94 per cent).

A 1. 2. 5. 1. *Income Groups*

There were no considerable differences between the two income groups, the lower income group having 7 per cent belonging to coal clubs and the higher 6 per cent (Table 6).

A 1. 2. 5. 2. *Analysis by Geographical Regions*

This analysis shows very clearly the much greater popularity of coal clubs in London and the South. The proportions are as follows :

Scotland	None
North	5 per cent
Midlands	5 ,,
London and South	15 ,,
South-West and Wales	4 ,,

A 1. 2. 5. 3. *Urban and Rural*

Coal club membership was confined almost entirely to the towns, there being only 5 members of a coal club in the rural sample of 730.

COST OF COAL

A 1. 2. 6. Question 3 asked " How much do you pay for a hundredweight of coal ? " Most of the households in the sample paid between 2*s*. 3*d*. and 3*s*. 5*d*. per hundredweight for their coal.

There were some differences between the town and the country as follows : 9 per cent of the town households paid between 1*s*. 10*d*. and 2*s*. 2*d*. compared with only 1 per cent of the country households, whereas 32 per cent of country households paid between 3*s*. 1*d*. and 3*s*. 10*d*. per hundredweight as compared with 25 per cent of town households (Table 7).

As would be expected there were considerable regional differences, the prices paid for coal being very much less in the North than in the South (Table 8).

In Region II, towns on a coalfield were compared with towns away from a coalfield, and a very striking difference emerged. In the coalfield towns 29 per cent of the households paid between 1*s*. 10*d*. and 2*s*. 2*d*. per hundredweight for their coal compared with only 3 per cent of the rest, whereas only 9 per cent of the households in coalfield towns paid between 2*s*. 8*d*. and 3*s*. compared with 48 per cent of the households in towns away from the coalfield (Table 9).

QUANTITY OF COAL BOUGHT

A 1. 2. 7. Information about the habits of coal buying are required for planning reasons. Table 10 shows that most people (36 per cent) buy 2 hundredweights at a time, 16 per cent buy 3 hundredweights, 14 per cent buy 1 hundredweight, 10 per cent buy five hundredweights, 9 per cent buy 5–10 hundredweights, and 8·1 per cent buy 10–20 hundredweights. It is interesting to note, in passing, that the intermediate quantity, four hundredweights, is only bought by 4 per cent of people. There are no important differences between the urban and rural sample.

A 1. 2. 7. 1. *Relation of the Quantity of Coal Bought to Cellar Capacity*

It appears unlikely that cellar capacity was a factor restricting the amount purchased except perhaps in a few cases where cellar capacity was less than 5 cwt.

Households with storage capacity of less than 5 cwt. were 465, 13 per cent of the sample ; of this number 42 per cent bought a quantity equal to their capacity, 54 per cent bought less and 4 per cent bought more (Table 11).

In households with a storage capacity of 5 cwt. or over, more than 90 per cent bought less than their capacity, and a little over 9 per cent bought a quantity equal to it. The numbers buying more were negligible.

A 1. 2. 7. 2. *Reasons for Purchasing Quantities Bought*

Question 5 asked why the householder bought the quantity of coal that she did. These reasons were related to the quantity bought and the importance of the reasons given was quite different in relation to different quantities. Over a fifth of the people bought all the coal that they could obtain at one time, and in most cases this was a quantity less than 5 cwt., that is in 963 cases out of 1036 these limitations were the result of the unofficial rationing which accompanied the coal shortage (Table 12). A further 1515 householders bought what they needed, as a rule, to cover either a weekly or a fortnightly or, in some cases, a longer period. The greatest number, 626, of these bought 2 cwt. at a time, 310 bought 3 cwt., 172 1 cwt. Of the rest 929 bought all they could afford, which in 253 cases was 1 cwt. and in 420 cases 2 cwt. The numbers giving other reasons were considerably smaller, and in some cases the reasons bore a very curious relation to the answer, for example, of the 335 people who stated that they liked a stock, 28 bought only 1 cwt.

A 1. 3. COOKING

A 1. 3. 1. The second section of the questionnaire was concerned with cooking.

Questions were asked to discover what fuel was used for cooking; what type of coal stove was used in the households where coal was used for cooking; what housewives thought of the cooking apparatus they had used and what preferences they had.

These results were analysed by the age of the housewife, by income, and in certain cases by region.

FUEL USED FOR COOKING

A 1. 3. 2. All housewives were asked " What fuel do you use for cooking in winter and in summer ? " (Question 6.)

Many housewives used more than one kind of fuel, particularly in winter, as will be seen from the results of this question. This results in the totals given below adding up to more than 100 per cent.

In total, 52 per cent of all housewives used coal, 72 per cent used gas, 9 per cent used electricity, and 3 per cent oil in winter (Table 13). In summer the proportions were coal 34 per cent, gas 76 per cent, electricity 10 per cent, and oil 3 per cent (Table 14). The coal figures show clearly the interdependence of cooking and space heating where this fuel is used.

A 1. 3. 2. 1. *Analysis by Geographical Regions*

In winter gas was used more than other fuels in all regions; in the North and South-West, both coal-producing regions, however, the proportions who used coal were almost as great (Table 13).

	GAS	COAL
Scotland	76 per cent	50 per cent
North	72 ,,	67 ,,
Midlands	75 ,,	45 ,,
London and South	77 ,,	36 ,,
S.W. and Wales	59 ,,	54 ,,

Electricity was used by a higher proportion in the Midlands, 12 per cent; regional differences were, however, small.

In summer gas was used in a slightly larger proportion of households in all regions except Scotland; the proportions using coal were, on the other hand, much less, particularly in London and the south (Table 14).

	GAS	COAL
Scotland	76 per cent	33 per cent
North	75 ,,	58 ,,
Midlands	79 ,,	25 ,,
London and South	82 ,,	9 ,,
S.W. and Wales	61 ,,	39 ,,

Electricity was used by about the same numbers as in winter.

A 1. 3. 2. 2. *Cooking in Households using Coal and some other Fuel*

There were 1848 households who used coal and some other fuel for cooking in the winter and 1156 who used coal and some other fuel for cooking in the summer. 86 per cent used gas, 8 per cent used electricity, and 6 per cent used oil as a second means of cooking in winter. In summer the proportions were roughly the same.

A 1. 3. 2. 3. *Urban and Rural*

There was a considerable difference between the town and the country in the results to this question ; whereas in towns over 90 per cent of the coal users employing other fuel used gas, in the country only 50 per cent used gas. In the country, however, the proportion using electricity and oil was considerably higher, being 16 per cent compared with 6 per cent, and 33 per cent compared with 1 per cent respectively. There was no very considerable difference between summer and winter (Table 15).

TYPE OF COAL GRATE USED FOR COOKING

A 1. 3. 3. The types of coal grate used for cooking were divided into four main groups : that with the oven and coal fire only ; the type which heated another room, commonly known as back-to-back ; that which heated water in a boiler from which the water was drawn with a tap or by a dipper ; and the type which heated water in a boiler connected to the sink or bathroom by pipes. The proportions found in the whole of the sample of 2783 households using coal for cooking was 58 per cent with the open fire, 3 per cent with the stove which heated another room, 10 per cent the type which heated water in a boiler, and 29 per cent the type which heated water for the kitchen or bathroom (Table 16).

A 1. 3. 3. 1. *Regional Differences*

There were considerable regional differences in the type of coal grates used for cooking, the main division being between those that heated water and those that did not (Table 17).

The proportion having an open fire only was highest in London (84 per cent) ; in the South-West it was 72 per cent, in Scotland 59 per cent, in the Midlands 55 per cent, and in the North 43 per cent.

The North had the greatest proportion of coal grates that heated water (53 per cent) and it also had the greatest proportion with the hot-water supply piped to kitchen and bathroom (43 per cent).

THERMOSTATS ON GAS COOKERS

A 1. 3. 4. The 3963 housewives with gas cookers were asked whether or not they had a thermostat attached to their stove. 21 per cent stated that they had this device and 79 per cent said they had not.

HOUSEWIVES' OPINIONS OF THE COOKING APPARATUS THEY HAVE USED

A 1. 3. 5. In Question 9 the housewife was asked to state her likes and dislikes about the cooking apparatus she had used.

In the analyses which follow, likes and dislikes of housewives of the cooking apparatus that they have used are expressed in a short code which is common to all types of cooking apparatus. They are as follows :

LIKES	DISLIKES
Like unspecified.	Dislike unspecified.
Cheap and economical.	Expensive.
Clean.	Dirty.
Easy or convenient.	Inconvenient.
Reliable.	Unreliable.
Cooks better.	Cooks badly.
Healthy.	Unhealthy.
Quick.	Slow.
Likes, related to some particular feature such as a thermostat.	Dislikes feature, *e.g.* hot-plate.
Used to it.	Dangerous.

The analysis as a whole shows that the most important factors for the housewife are cleanliness, economy, and convenience. In order to make the bare code a little more real, brief descriptions are given below in relation to each type of fuel.

A 1. 3. 5. 1. *Coal*

Likes

The largest category, that of unspecified like, was expressed in many cases where the coal oven was the type of cooking apparatus with which the housewife was familiar (Table 18). She could express no particular reason for liking it and, on the other hand, had often no other experience with which to compare it.

The category of " cheap and economical," which was also important, can be illustrated by the reply of one housewife who stated, " The range works all right and it is cheaper to cook with because the fire is in all the time." The fact that the fire was always available was, in some cases, the reason why the coal oven was considered to be more convenient.

A very large number of persons using coal said they liked it because it cooked better. This in very many cases appeared to be simple prejudice, as this answer was most common in the North and often was expressed by housewives who had no other experience. In some cases this opinion was expressed with reference to some other kind of stove, particularly in the case of gas and sometimes in the case of electricity. In some cases it was believed that coal cooked better than gas because of the absence of any fumes in the cooking process.

Dislikes

The dislikes in relation to coal cookers are fairly obvious. They are regarded in some cases as expensive on account of the large quantities of coal they use, and dirty because many of them, particularly the elaborate kitchen ranges and the back-to-back grates, need considerable attention to keep the flues free from soot. In some cases the difficulty of cooking by coal in summer was regarded as a serious inconvenience.

A 1. 3. 5. 2. *Gas*

Likes

As with coal, a simple unspecific like was very often expressed, but perhaps the most important feature of gas cooking to be praised was the convenience of gas, inasmuch as in most cases it was necessary only to use approximately the amount of heat necessary for any particular operation, with the choice of various sizes of boiling ring, a grill, and an oven. The speed with which the kettle can be boiled by gas was also a feature praised by a very large number (Table 18).

Dislikes

A number of housewives consider gas cooking expensive, and an even greater number objected to gas because it was dirty, particularly because of the fumes.

A 1. 3. 5. 3. *Electricity*

Likes and dislikes in the case of electricity are fairly straightforward. The cleanliness of electric cooking is by far the most important feature praised, whereas expense, inconvenience of its hot-plates in relation to kettle boiling, and the slowness of the electric cooker in general were the most important dislikes.

A 1. 3. 5. 4. *Comparison of the Main Types of Cooking Fuels*

It is interesting to note how the different attitudes apply to the three main types of cooking (Table 18). The first category of housewives with unspecified likes and its corresponding category of housewives with unspecified dislikes are much more important in relation to coal and gas ; 33 per cent and 28 per cent, and 10 per cent and 12 per cent, compared with 15 per cent and 6 per cent in the case of electricity. This difference is perhaps due to the fact that people using electric cookers had changed from some other type deliberately, whereas in the case of coal and gas the housewives were expressing an opinion about the apparatus with which they had become familiar.

More housewives mentioned coal and electricity as being " cheap and economical " in their reasons for liking one type of fuel. On the other hand, amongst the expressions of dislike the expense of electricity was mentioned by a greater proportion disliking electricity than of those who disliked any other type of fuel—this may be a reflection of different electricity tariffs in different parts of the country.

The majority of the housewives who had used electricity praised its cleanliness, whereas cleanliness was not an important factor in the minds of those housewives who had used either coal or gas.

Most of the housewives who gave a specific reason for preferring gas did so on account of its convenience, whereas the greatest proportion of housewives preferring coal did so because they believed that it cooked better. The inconvenience of coal was the main reason for housewives disliking it.

It is difficult to know exactly what the answers " cooks better " mean. These are a large proportion in the case of both coal and electricity, but a very small proportion in the case of the housewives' likes about gas.

There were no important differences between the attitudes of the two income groups.

A 1. 3. 5. 5. *Analysis by Region*

There were a few points of interest in the analysis of these questions by regions. The North and Scotland had the highest proportions of unspecified likes for coal and gas. In London and the South these proportions were lowest.

These unspecified likes were offset in this region by a larger proportion of specific likes, particularly " cheap and economical " and " cooks better " in the case of coal and clean in the case of gas.

PREFERENCES FOR COOKING APPARATUS AND REASONS FOR PREFERENCE

A 1. 3. 6. There were answers to Question 10, " What type of cooking apparatus would you like best ? " in 4808 cases where age was known. The main preferences for the whole sample were coal 20 per cent, gas 47 per cent, electricity 32·8 per cent, and oil 0·2 per cent.

A 1. 3. 6. 1. *Analysis by Age*

There were some differences in different age-groups in their preferences in relation to coal and electricity which illustrate the greater conservatism of age (Table 19 A). The four age-groups, under 30, 30–40, 40–50, and over 50, showed the following proportions preferring coal: 12 per cent, 16 per cent, 21 per cent, 29 per cent, whereas the preferences for electricity amongst the same groups show an opposite trend: 42·2 per cent, 39·1 per cent, 32 per cent, and 22·1 per cent. The proportions preferring gas were, in all cases, about the same, ranging from 44·6 per cent to 48·8 per cent.

A 1. 3. 6. 2. *Analysis by Age and by Income Group*

Income level appears to affect preference for two reasons ; electric cooking is believed to be more expensive, whereas coal cooking, which in many cases is combined with space heating, is regarded as being less expensive, also the poorer housewives are more conservative than those in the higher income group. In each age-group the proportion preferring coal is higher amongst the families with under £160 per annum ; for example, in the under 30 age-group : 14 per cent in the lower income group compared with 10 per cent in the higher income group ; and in the over 50 group : 31 per cent compared with 25 per cent. Preferences for electricity, however, show a difference in the opposite direction, 37 per cent of the housewives under 30 in the lower income category preferring electricity, compared with 47 per cent in the higher income category. In the older group the total is naturally less, but the relations of the two income groups is similar, the proportions preferring electricity being 20 per cent and 25 per cent respectively (Table 19 B).

The total figures summarize the position. In the higher income group the proportions preferring coal, gas, and electricity are 18 per cent, 46 per cent, and 37 per cent. In the lower income group the proportions are 24 per cent, 48 per cent, and 26 per cent respectively.

A 1. 3. 6. 3. *Analysis by Geographical Regions*

Question 10 was further analysed into geographical regions and some very interesting differences emerged (Table 20). Coal was preferred by a much greater proportion of housewives in the North (31 per cent), compared with 19 per cent in the South-West, 17 per cent in the Midlands, 14 per cent in London and in Scotland.

The preference for gas is highest in London, 54 per cent, and lowest in the North, 36 per cent, whereas the proportions liking electricity, although somewhat higher in Scotland, are about the same in all regions, the range being from 30 per cent in South-West to 38 per cent in Scotland.

REASONS FOR PREFERRING DIFFERENT COOKING FUELS

A 1. 3. 7. The answers to Question 10, "What type of cooking apparatus do you like best?" were related to the answers given in Question 11, "What are your reasons for liking this?" and they have been analysed into age-groups, this being considered the most important factor affecting choice. The answers were grouped as follows:

1. An unspecified like.
2. Cheap or economical.
3. Clean.
4. Easy.
5. Reliable.
6. Cooks better.
7. Healthy.
8. Quick.
9. Likes feature, as for example, thermostat.
10. Used to it.
11. More modern.
12. Other people have recommended it.
13. Safe.
14. Heats the house or room.

The order of the total figures shows the main reasons for preference. The most important reasons for preferring coal are the following:

Cooks better	29	per cent	of cases
Used to it	27	,,	,,
Cheap and economical	22	,,	,,
Heats the house or room	12	,,	,,
Easy	9	,,	,,

In the case of gas the most important reason is "Used to it," mentioned by 32 per cent of housewives; the second most important reason is, "Easy or convenient", given in 24 per cent of cases; the third most important reason is the "Cleanliness" of gas cooking; the fourth and fifth are the "Quickness" of gas cooking, and the "Cheapness" of gas cooking respectively.

The preferences in relation to electricity are rather different. By far the most important feature is "Cleanliness" of electric cooking (69 per cent); the next main important reason is "Cheap and economical" (27 per cent), followed by "Easy" (18 per cent). In contrast to gas and coal, only 2 per cent prefer it because they are "Used to it." This may be related to the fact that only about half of the housewives preferring electric cooking had had experience of it (Table 21).

A 1. 3. 7. 1. *Analysis by Age*

There are some small features in the analysis by age which are worth noting. In the case of cooking by coal there are differences in the proportions in the categories who find coal cooking easy and who are used to coal cooking. It is in the under 30 group that the largest proportion of answers finding coal cooking easy are found. This is no doubt due to the fact that the younger housewives are very often living in more modern houses. On the other hand, it is in the older groups that there is a larger proportion of housewives who prefer coal because they are used to it.

There are no very great age differences in the preferences expressed for gas cooking or for electricity.

THE INFLUENCE OF EXPERIENCE ON PREFERENCES FOR COOKING FUEL

A 1. 3. 8. The answers about the types of cooking apparatus preferred were analysed further into two main groups; those who had used the type of apparatus that they preferred and those who had not used it (Table 22). The purpose of these questions was to ascertain how far preference was based on experience or was influenced by propaganda or by the views of others.

We have counted in the " Yes " answers to the question " Have you ever used it ? " all those housewives who had had some experience with the type of cooking apparatus that they like best in houses other than their own, as for example, " In my mother's house," " At my sister's," and in some cases at the houses of friends or other relatives, so that the definition of " Yes " in this case is a broad one.

The main preferences have already been discussed, and in this analysis the main point of interest is to compare how far the preferences for each type of fuel are based on experience or not.

Of the total answers 74 per cent were based on experience and 26 per cent were preferences not related to actual experience of the type of apparatus preferred. There was some difference between the age-groups which can be best illustrated by comparing the youngest group with the oldest. In the youngest group, 69 per cent preferred a type of apparatus which they had tried, whilst 31 per cent expressed preference for apparatus which they had never used. In the oldest group, on the other hand, the proportions were 78 per cent and 22 per cent respectively, illustrating the greater conservatism of age.

A comparison between the three main types of cooking shows an interesting feature, namely, that in the case of electricity in about half of the cases the preference is not related to actual experience and is possibly due to publicity.

The proportions preferring coal, gas, and electricity are as follows:

	COAL	GAS	ELECTRICITY
With experience	89 per cent	85 per cent	49 per cent
Without experience	11 ,,	15 ,,	51 ,,

There is very little difference between the four age-groups for the preferences taken individually.

A 1. 4. SPACE HEATING

A 1. 4. 1. Information about space heating was obtained from the answers to Question 13: " At what times and on what days do you heat the following rooms at the present time of year and in what way ? "

Information obtained from this question was summarized to give the number of hours the following rooms were heated: kitchen, kitchen-sitting room, sitting room and bedrooms, and the fuel used to heat them.

Information was also obtained about the total number of rooms heated in the household in a day at that time of year (February-March).

In the analyses which follow there are, in certain cases, slight inconsistencies in the totals for the groups into which the data have been analysed. These arise from the fact that in a few cases some relevant information about the household was omitted from answers to the questionnaire.

The information obtained has been grouped under three main headings:

i. The number of rooms heated; which is further analysed to compare the number of rooms heated in houses with the number of rooms heated in flats; a comparison of the number of rooms heated in the two income groups and in families with and without children.

ii. The time that rooms were heated. This has been further analysed into regions and into urban and rural districts.

iii. The fuel used to heat rooms. A total picture is given and also details for the sitting room and the bedrooms.

NUMBER OF ROOMS HEATED

A 1. 4. 2. Summarizing the data, it is seen that at the time the Survey was made (February-March) one room only was heated in about 74 per cent of all the households in our sample, two rooms in 23 per cent, and three rooms or more in 3 per cent (Table 23). There was no significant difference between the number of rooms heated on weekdays and on Sundays.

There were 3897 households who heated one room only, and in all but three cases it was one of the living rooms.

In 1197 households where two rooms were heated, these rooms were a living room and bedroom in 681 cases (57 per cent), and two living rooms in 516 cases (43 per cent).

Three rooms were heated in 116 cases, in nine of which there were three living rooms, and in the rest two living rooms and one bedroom.

In all the 58 households where four rooms were heated there were three living rooms and a bedroom.

A 1. 4. 2. 1. *Houses Compared with Flats*

The sample was analysed into households occupying houses and households occupying flats, and these were further sub-divided into the two income groups (Table 24).

The main picture is that two or more rooms were heated more often by families occupying flats than by families occupying houses ; some 35 per cent of flats had two or more rooms heated compared with 24 per cent of the houses.

This pattern was true for both income groups, although to a greater extent the higher income group in both flats and houses heated more than one room ; this was particularly so in the case of flat dwellers (Table 24). The proportions are as follows :

Houses heating 2 or more rooms	(income under £160 p.a.)	20	per cent
,, ,, 2 ,, ,,	(,, over £160 p.a.)	27	,,
Flats heating 2 or more rooms	(income under £160 p.a.)	28	,,
,, ,, 2 ,, ,,	(,, over £160 p.a.)	41	,,

This helps to a considerable extent to account for the higher expenditure on heating by flat dwellers, particularly in the upper income group.

A 1. 4. 2. 2. *Families with Children Compared with Those Without*

There is very little difference between these two groups in the sample. Whilst on weekdays fewer families with school children heat two rooms than do families without, on Sundays this tendency is reversed. The differences, however, are very slight.

LENGTH OF TIME ROOMS ARE HEATED

A 1. 4. 3. This again refers to February and March, the time of the Survey.

A 1. 4. 3. 1. *Kitchen*

Sculleries were included with kitchens for the purpose of this analysis, since the scullery was very rarely heated, and it was impracticable to deal with both separately. It does not affect the kitchen picture to any extent (Table 25).

The total picture for weekdays is as follows :

Households heating kitchen for less than 8 hours	were	17	per cent of the sample
8–10	,,	7	,,
10–12	,,	19	,,
12–14	,,	32	,,
14–16	,,	17	,,
Over 16	,,	8	,,

On Sundays the kitchen is heated for a less number of hours in many cases, the proportions being as follows :

Less than 8	hours	19	per cent
8–10	,,	11	,,
10–12	,,	29	,,
12–14	,,	25	,,
14–16	,,	10	,,
Over 16	,,	6	,,

The kitchen was heated in 659 cases on weekdays and 637 on Sundays.

A 1. 4. 3. 2. *Kitchen-Sitting Room*

The kitchen-sitting room was heated much more often than the kitchen, and there was only a small difference between weekdays and Sundays in the total number of kitchen-sitting rooms heated (Table 26). The figures were :

3788 Kitchen-sitting rooms heated on weekdays
3772 ,, ,, ,, Sundays.

The times that the kitchen-sitting room was heated on weekdays were as follows :

Less than 4	hours in	1	per cent	of households
4–8	,,	3	,,	,,
8–10	,,	7	,,	,,
10–12	,,	20	,,	,,
12–14	,,	37	,,	,,
14–16	,,	23	,,	,,
Over 16	,,	9	,,	,,

The results for Sunday show that, as in the case of the kitchen, the kitchen-sitting room is heated for a rather shorter time on Sundays than on weekdays. The results are as follows :

Less than 4	hours in	1	per cent cases
4–8	,,	4	,,
8–10	,,	11	,,
10–12	,,	30	,,
12–14	,,	34	,,
14–16	,,	13	,,
Over 16	,,	7	,,

A 1. 4. 3. 3. *Sitting Room*

The sitting room was heated in 1193 households on weekdays and in 1416 households on Sundays, quite a considerable increase on Sunday compared with the other rooms (Table 27).

The proportions of the total number of sitting rooms which were heated for different times on weekdays is given below :

Less than 4	hours in	11	per cent cases
4–8	,,	12	,,
8–10	,,	10	,,
10–12	,,	19	,,
12–14	,	29	,,
14–16	,,	13	,,
Over 16	,,	6	,,

On Sundays the results were :

Less than 4	hours in	7	per cent cases
4–8	,,	16	,,
8–10	,,	16	,,
10–12	,,	28	,,
12–14	,,	23	,,
14–16	,,	6	,,
Over 16	,,	4	,,

It will be seen that, as in the case of the other downstair rooms, the sitting room is heated for a rather less number of hours on Sunday than on weekdays although, as has been noted, more sitting rooms are heated on Sundays.

It is worth noting that the proportion of sitting rooms which are heated for a long time on weekdays is somewhat less than the proportion of kitchen-sitting rooms that are so heated.

A 1. 4. 3. 4. *Bedrooms*

The analysis of bedrooms is given in a form slightly different from that of the other rooms. In almost all of the sample there were rooms which were used as bedrooms only, and it is thus possible to compare, not only the amount of time that each bedroom was heated, but also to include in the sample the cases where the bedrooms were not heated. This was not possible in the cases of the other rooms as, in many instances, kitchen, kitchen-sitting room, and sitting room were used for much the same purpose, and it did not necessarily follow that, because one of them was not heated, another room was not being heated and serving the purpose. Where more than one bedroom was heated, that which was heated longest was taken.

Bedrooms were not heated in nearly 87 per cent of all households on both weekdays and Sundays (Table 28).

281 bedrooms of the total number (6 per cent) were heated for an hour or less, 128 (2 per cent) were heated for less than 2 hours ; 110 (2 per cent) were heated for between 2 to 4 hours ; and 3 per cent of bedrooms were heated for more than 4 hours. There was no difference between weekdays and Sundays.

TIMES ROOMS WERE HEATED—ANALYSED BY REGIONS

A 1 4. 3. 5. The analysis by degree-day Regions presents certain difficulties inasmuch as it was only possible to account for the total time that a room was heated and not for the intensity of the heating, and whilst climatic conditions may have influenced to some extent the number of hours that any room was heated, there may be other factors involved as well which are not so susceptible to analysis. It is in the case of bedrooms that the regional analysis is most striking.

A 1. 4. 3. 6. *Kitchen*

In the case of the kitchen it was possible to compare degree-day Region II (4500–5000) with degree-day Region IV (under 4000) (Table 25). The proportion of kitchens which were heated for less than 8 hours was twice as large in degree-day Region IV—17 per cent—as in degree-day Region II (refers to urban districts).

A 1. 4. 3. 7. *Kitchen-Sitting Room*

There are no very great regional differences in the time the kitchen-sitting room is heated in towns, although the proportions of kitchen-sitting rooms which are heated for less than 10 hours does vary inversely with the number of degree-days (Table 26). These proportions are : Region II, 7 per cent ; Region III, 9 per cent ; and Region IV, 19 per cent.

The length of time that rooms were heated in the warmest region was clearly less than the times in the colder regions, although within the colder regions themselves the difference is not so clear, Region III, for example, having almost as large a proportion in the 16 hours or over group as Region I.

The situation in the rural areas is rather similar.

On Sundays the same picture is generally true, but the kitchen-sitting room is. on the whole, heated rather less on Sundays than weekdays.

A 1. 4. 3. 8. *Sitting Room*

The analysis of the sitting room figures in towns shows the influence of the degree-day rather more clearly than the other rooms, possibly because in many cases this is a room which is less used than the kitchen-sitting room and is a room which is used in a subsidiary way to the kitchen-sitting room. The proportions heated for less than 4 hours vary clearly with the degree-day figure, being 7 per cent in the coldest of the three regions for which we have a sufficient sample, 12 per cent in the next, and 12 per cent in the warmest (Table 27). The next two groups (4–8

and 8–10 hours) taken together show the same pattern, the proportions in each region being 17 per cent, 20 per cent, and 27 per cent respectively. This general tendency in the lower heating ranges is reversed in the higher ranges, as one would expect, if heating depends on temperature. If the proportion of sitting rooms heated for more than 12 hours is taken, the figures are, going from the coldest to the warmest region, 59 per cent, 53 per cent, and 41 per cent.

The numbers in the rural sample are not large enough to be significant.

The heating of the sitting room on Sundays follows the same pattern, although as in the case of other rooms the sitting room is heated less on Sundays than on weekdays.

A 1. 4. 3. 9. *Bedrooms*

The heating of bedrooms has been analysed to include the bedrooms which were not heated at all as well as those which were heated, as has already been explained; there being no alternative inside the category of bedrooms, this proportion is as significant as the duration of the time for which the bedrooms are heated.

In the coldest region 25 per cent of bedrooms were heated, in the next coldest region 15 per cent, in the next 10 per cent, and in the warmest region 10 per cent (Table 28). The influence of the climate is clearly shown in this analysis. It is borne out in the analysis of the times that the rooms were heated, particularly if the coldest region is compared with the warmest. In the coldest region 8 per cent of bedrooms were heated for one hour or less compared with 4 per cent in the warmest, 5 per cent were heated for 1–2 hours compared with 3 per cent, 8 per cent for 2–4 hours compared with 1 per cent, and 3 per cent for more than 4 hours compared with 2 per cent (this refers to the urban sample).

In the rural sample the same tendency is present although the differences are rather less.

In contrast to the other rooms the times during which bedrooms are heated are almost identical on both Sundays and weekdays.

COALFIELD AREA COMPARED WITH NON-COALFIELD AREA

A 1. 4. 4. It has been suggested that, in the Northern region, households on the coalfield might heat their rooms for longer periods than houses away from the coalfield. An analysis was made of the bedrooms, sitting rooms, and kitchen-sitting rooms.

In the case of bedrooms it was found that, in fact, slightly more bedrooms were heated on the coalfield than on the non-coalfield area, 11 per cent compared with 7 per cent, the figures being about the same for both weekdays and Sundays.

In the case of sitting rooms the numbers were too small for our purpose, and in the case of the kitchen-sitting room there was almost no difference in the proportion up to 14 to 16 hours, although in the case of over 16 hours the coalfield households were heated to this extent in 13 per cent of the sample compared with 8 per cent of the non-coalfield sample.

FUEL USED TO HEAT ROOMS

A 1. 4. 5. By far the most important fuel used for heating was coal. 95 per cent of all kitchens were heated by coal, 96 per cent of all kitchen-sitting rooms were heated by coal, 96 per cent of all sitting rooms were heated by coal, and 48 per cent of bedrooms. It is clear from these proportions that other types of heating are used mainly to supply short period heating in bedrooms.

A 1. 4. 5. 1. *Sitting Room*

Separate analyses for the bedrooms and sitting rooms have been made (Table 29). This shows that of the 1192 sitting rooms, 16 were heated with gas, 29 with electricity, 10 with oil, and 1137 with coal. There was no difference between weekdays and Sundays.

A 1. 4. 5. 2. *Bedrooms*

In the case of the bedrooms the other fuels were important (Table 30). Of the 682 bedrooms heated, 323 were heated by coal, 104 were heated by gas, 205 by electricity, and 50 by oil.

Although fuels other than coal were important for heating bedrooms, it is interesting to notice that for heating for longer periods coal is the most important fuel. Where rooms were heated for more than 8 hours, coal was used in 89 per cent of the cases, but where bedrooms were heated for less than 8 hours, the proportions using coal, gas, and electricity were respectively 41 per cent, 17 per cent, and 34 per cent.

CONCLUSION

A 1. 4. 6. Most of the households visited heated only one room, but about one quarter heated two or more rooms. In most cases the living rooms were heated for 8 hours or more, often for 12–14 hours, and in a few cases as many as 16 hours. Only a small proportion of the bedrooms were heated and these not often for more than 4 hours.

The time that the rooms were heated bears a relation to the degree-day regions and although this was not clearly defined in all cases, it is best shown in the sitting room and bedrooms.

Of the fuels used, coal was almost exclusively used to heat every room except the bedrooms, where other fuels accounted for a little over half of the heating.

A 1. 5. CENTRAL HEATING

A 1. 5. 0. In the tabulated results there are the main reactions to the direct questions about central heating. There are, however, a number of wider points which arose in the course of the interview. The following are some of the points raised :

RELATION OF CENTRAL HEATING TO COOKING

A 1. 5. 1. In some parts of the country, more particularly in the North of England coalfield areas, housewives found it very difficult to imagine central heating in relation to their present cooking habits, as will be seen from the replies in the question about cooking preferences. In these areas where there is a long tradition of coal cooking and where coal has been cheap, there is a strong prejudice against any other form of cooking.

Bread-baking again introduces a similar complication. In the North of England the large kitchen range was designed to cook bread for a family in one session. The small gas stove so often supplied, and the gas grill familiar in Scotland, would make home baking impossible, so that when the question of central heating was raised the problem of breadbaking was involved.

THE FIRE AS THE CENTRE OF THE LIVING ROOM

A 1. 5. 2. In their discussions with housewives our field workers reported that a very great many people found central heating would deprive them of a very essential focal point of family activity, as is expressed in such remarks as, "You couldn't very well sit round a radiator after tea," or "The room would be cheerless without a nice bright fire." The need for some focal point for the ordinary social activities of the family was very strongly emphasized. The gas fire would, perhaps, fill this need, but an electric fire was often thought to be less satisfactory, unless, as was mentioned in one case, it was an electric fire designed to look like a coal fire with the flickering shadow and flame. Another factor was that the fire was "company" for the housewife when she was alone during the day, and that she would miss having it and having to pay it attention.

CLOTHES DRYING

A 1. 5. 3. Some housewives call attention to the fact that the fire is used very much in the winter for the drying and airing of clothes. The clothes-horse, a common article of domestic furniture, is designed for use essentially with the open coal fire.

It should also be pointed out that there was often a division of opinion within the family about coal fires and central heating. In some cases the wives would prefer central heating on account of the saving in labour, but the husbands (this was mentioned particularly in farming areas) looked forward to the fire on their return from work. In other cases the wives were conservative and the husbands more willing to experiment.

LIKES AND DISLIKES ABOUT CENTRAL HEATING

A 1. 5. 4. To introduce the subject of central heating and to prepare the housewife for the later questions, she was asked if she had any likes or dislikes about central heating. This question was entirely unprompted.

There were some 5187 answers, of which 34 per cent were favourable, 44 per cent were neutral, and 21 per cent were unfavourable (Table 31).

Of the favourable replies, most, 26 per cent, were an unspecified preference. In the neutral group the greater proportion, 35 per cent, were unable to express any opinion.

In the unfavourable group the most important answer was " cheerless," 9 per cent.

There were no appreciable differences in the preference of the different age-groups, or of persons living in old, as compared with new, houses.

A 1. 5. 4. 1. *Likes and Dislikes about Central Heating: Analysed by Degree-Day Regions*

The analysis of likes and dislikes by region show in a qualitative form the main conclusions of the statistical analysis.

The totals of answers in the three categories show interesting differences. Central heating is liked most in the warmest region, disliked equally in the three colder regions, whilst the degree-day Regions II and III have the largest proportions of neutral answers.

			LIKES	NEUTRAL	DISLIKES
Region	I.	5000–5500 degree-days	28 per cent	30 per cent	41 per cent
,,	II.	4500–5000 ,,	29 ,,	46 ,,	24 ,,
,,	III.	4000–4500 ,,	28 ,,	50 ,,	21 ,,
,,	IV.	Under 4000 ,,	43 ,,	39 ,,	17 ,,

There were 5187 answers to this question. The proportion of these answers which stated that central heating was cheerless was 20 per cent in the coldest region and only 5 per cent in the warmest region. It should be said, however, that the psychological comfort derived from a fire may be more appreciated in colder and less sunny parts of the country than it is in the warmer parts, so that this objection to central heating is not wholly irrational. The proportion of housewives who stated that they did not like central heating was 14 per cent in the coldest region and only 6 per cent in the warmest.

CENTRAL HEATING EXPERIENCE

A 1. 5. 5. Housewives were asked whether they had had any direct experience of central heating.

Much of the experience was that of public institutions, hotels, hospitals, libraries, work places, offices, or private houses in the case of former domestic servants, and in a few cases of experience in houses and flats (a few in Canada).

Of the 5175 housewives who answered this question one-third had had direct experience of central heating and two-thirds had not (Table 32).

There was no important difference between the income groups.

A 1. 5. 5. 1. *The Influence of Central Heating Experience on Likes and Dislikes about Central Heating*

In this question the comments made by housewives who had had some experience of central heating were compared with the comments made by those who stated that they had had none (Table 33).

There were 1671 comments made by housewives with experience of central heating and 3331 made by housewives without this experience.

The first category, those who would not offer any determined opinion, was 16 per cent of the answers of housewives with experience, as compared with 45 per cent of the housewives with no such experience. Those stating they preferred it were 38 per cent of the housewives with central heating experience and 21 per cent of the others. These were the main categories in which there were considerable differences. They show, however, that experience is a very important factor in influencing opinion on this subject.

A 1. 5. 5. 2. *Analysis by Age*

The analysis by age shows that the proportion who were undetermined was the same, or nearly so, in each age-group with experience, between 14 per cent and 17 per cent, and similarly the same in each age-group with no experience, between 44 per cent and 46 per cent (Table 33). There were likewise only small differences in the age-groups amongst those who had experience and preferred it and those who had no experience and preferred it.

A 1. 5. 5. 3. *Analysis by Region*

In this analysis the same tendency shows in each region, namely, that the housewives with experience of central heating are more positive in their opinions, and a greater proportion prefer it. In a similar way to the other analyses, housewives in the warmer regions appear to have a greater preference for central heating than those in the colder region (the number of housewives with experience of central heating in Region I is too small to be useful).

A 1. 5. 5. 4. *Likes and Dislikes of Central Heating Analysed by Urban and Rural Districts*

The total of answers by housewives who had had experience or had not had experience of central heating were analysed into Urban and Rural, and certain differences emerged, particularly in the sample of housewives who had not had any experience of central heating.

Amongst those who had had experience, of central heating, there was a greater proportion of answers indicating preference amongst the urban housewives than amongst the rural, 40 per cent compared with 30 per cent. There was, on the other hand, very little difference in the proportion of answers which stated they were unable to express an opinion. Between these two opinions the neutral, "no objection," was expressed by rather more rural housewives than urban housewives.

The curious feature of the urban sample with experience was the large proportion (15 per cent) of answers which stated that central heating was unhealthy.

Amongst the housewives without experience, there was a greater proportion who could not express an opinion in the country than in the town—43 per cent in the town compared with 53 per cent in the country. The neutral category of "no objection" was again slightly larger in the country than in the town, and although, as has already been seen, the proportion of persons who would prefer central heating was much smaller amongst those without experience of it, this was much less in the country than in the town—13 per cent compared with 22 per cent.

HOUSEWIVES' VIEWS ABOUT SOME ALTERNATIVE CENTRAL HEATING AND HOT-WATER SUPPLY SYSTEMS

A 1. 5. 6. The subject of central heating having thus been introduced, a series of questions were asked to discover to what extent housewives were willing to accept and pay for some alternative central heating and hot-water supply systems (Questions 15 to 22). As will be seen from the questionnaire the saving of labour by these schemes was pointed out. The alternatives were :

i. Central heating in all rooms and constant hot water in the kitchen and bathroom without a boiler in the house.

ii. The same but without coal fires (Questions 15, 16, and 17).

iii. Central heating in the sitting room and constant hot water in the kitchen and bathroom without a boiler in the house.

iv. The same but without coal fires (Questions 18, 19, and 20).

Housewives were also asked what part of the house they would prefer to have heated in this way and the reason for their choice (Questions 21 and 22).

The results are given question by question in the following pages.

Question 15:

"*Would you like central heating in all rooms and constant hot water in the bathroom and kitchen?*"

A 1. 5. 6. 1. Some 4984 housewives answered this question, of whom 3724, 75 per cent, stated that they would like it (Table 35).

A 1. 5. 6. 11. *Analysis by Age.* The analysis by age showed that the greatest proportion of housewives who would like central heating were in the youngest age-group, with less proportions in each of the older groups, although the difference was not large, 80 per cent in the under 30's as compared with 68 per cent in the over 50's (Table 34). This answer may be related to the greater conservatism of the older people in relation to cooking.

A 1. 5. 6. 12. *Analysis by Income.* In this analysis a slightly greater proportion of housewives in the higher income group would like this form of central heating than in the lower, 77 per cent compared with 73 per cent.

A 1. 5. 6. 13. *Analysis by Degree-Day Regions.* It was decided to analyse the results first of all by region on a degree-day basis to see whether or not there was any relation between the attitude to central heating and the real needs judged by this basis (Table 35). It was found, however, that the opposite was the case: Region I, the coldest, had only 45 per cent wanting central heating, Region II 71 per cent, Region III 74 per cent, and Region IV 80 per cent. It seems, therefore, that the attitude to central heating is not related to heating needs. The answers are, therefore, analysed further on a geographical basis because although Region I, on a degree-day basis, is very largely the Pennine region, and although Region IV is mainly south, there is a considerable spread.

A 1. 5. 6. 14. *Analysis by Geographical Regions.* The differences in the geographical regions are less than in the degree-day regions, but they show a curious feature, namely, that in England there is no great difference between the Midlands, London, and the South-West, 78 per cent, 80 per cent, and 76 per cent of the housewives in each region saying they would like central heating, but the proportion in the North is smaller, being only 68 per cent. The proportion in Scotland is 74 per cent (Table 36).

A 1. 5. 6. 15. *Analysis by Urban and Rural Districts.* There was a small difference between the preferences of the urban and rural housewife, as would be expected. The proportion of urban housewives who would like central heating was 76 per cent compared with 69 per cent of the rural sample (Table 37).

A 1. 5. 6. 16. *Old and New Houses.* There was no important difference between the attitudes of housewives living in old and new houses.

A 1. 5. 6. 2. *Payment for Central Heating to All Rooms and Constant Hot Water to Bathroom and Kitchen.*

Question 16 asked, "If there was a charge for the winter months, how much would you be prepared to pay?" and suggestions from 5*s.* to 2*s.* 6*d.* a week were made in dutch auction style (Table 38). About 2600 housewives were prepared to make some payment and about 4000 housewives answered the question. This is somewhat more than the total number who stated that they would like central heating and is accounted for by the fact that a few housewives who had already stated that they did not want central heating answered that they did not know how much they would be prepared to pay for it.

Of the total number who answered this question, about a third were prepared to pay up to 5*s.* a week, one-half would pay up to 3*s.* 6*d.*, whilst two-thirds would pay up to 2*s.* 6*d.*; the rest would either pay nothing or were unable to make a decision.

A 1. 5. 6. 21. *Analysis by Income.* There is a considerable difference between income groups.

The higher income group is much more positive in its opinions; only 24 per cent said they did not know what they would pay, as compared with 32 per cent in the lower income group (Table 38).

The higher income groups are also prepared to pay rather more; for example, 39 per cent are prepared to pay up to 5*s.* a week compared with 25 per cent in the lower income group. The proportions willing to pay up to 3*s.* 6*d.* and up to 2*s.* 6*d.* are likewise higher in the higher income group. The proportion unwilling to pay anything for this service is lower in the higher income group, 6 per cent compared with 10 per cent.

A 1. 5. 6. 22. *Analysis by Region.* The analysis by region shows a considerable difference when it is compared with the analysis of Question 15 which asked whether people would like central heating (Table 39). Although in Question 15 the number who stated that they would like central heating was lowest in the colder regions and highest in the warmest, when the more definite question of weighing the value of central heating against a cash outlay was put it was found that, although central heating was of least cash value in the coldest region, the second lowest proportion of housewives who were prepared to pay 5*s.* a week, the top price, was found in the warmest region.

In the up to 3*s.* 6*d.* group the order from the highest to the lowest proportions was Region III, Region I, Region II, and Region IV.

In the up to 2*s.* 6*d.* group the order was Region III, Region II, Region I, and Region IV.

These results show a conflict between two factors, one the greater conservatism of the North and the other the need for the service in relation to climate.

The warmest region also had the highest proportion of persons in it who answered that they did not know what they would be prepared to pay, indicating a less decided attitude towards central heating in face of a possible charge for the service.

A 1. 5. 6. 23. *Urban and Rural Districts.* There were no very great differences between the urban and the rural sample.

A 1. 5. 6. 24. *Analysis by Age.* As would be expected from other analyses that have been made by age, the older housewives in the sample were less willing to pay for central heating (Table 40). The proportion in the youngest group who were prepared to pay up to 5*s.* a week was 38 per cent as compared with 28 per cent in the oldest group. In the category who were prepared to pay 3*s.* 6*d.* the proportions were 59 per cent compared with 43 per cent, and in the category who were prepared to pay 2*s.* 6*d.* 73 per cent compared with 55 per cent.

A 1. 5. 6. 25. *Analysis into Old and New Houses.* There was no important difference between the attitudes of housewives living in old and those living in new houses.

Question 17:

"*Would you still like central heating in all rooms and constant hot water if there were no coal fireplace in the house?*"

A 1. 5. 6. 3. This question was devised to find out how far there was a prejudice in favour of the open fire in the minds of housewives, as it was a subject which was frequently commented upon during the interview and one about which there was considerable feeling. The analysis of the 4178 answers (Table 41) to this question showed that 40 per cent of the housewives would like central heating under these conditions compared with 60 per cent who would not. These figures compared with 75 per cent and 25 per cent in the case of the more open question which did not mention "*No* coal fireplaces," so that this represented a loss of nearly a half of the housewives who were in favour of central heating.

A 1. 5. 6. 31. *Analysis by Income.* There was no important difference between the two income groups in this analysis.

A 1. 5. 6. 32. *Analysis by Degree-Day Region.* The analysis by region shows a similar trend to the analysis of Questions 15, in so far as the most conservative groups are those in the coldest region, the proportion here being only 21 per cent, little more than half the national proportion (Table 41). The other three regions all had about 40 per cent who would like this form of central heating.

A 1. 5. 6. 33. *Urban and Rural.* There was no significant difference between the answers of urban and rural housewives.

Question 18:

"*Would you like central heating in the sitting room and constant hot water in the kitchen and bathroom?*"

A 1. 5. 6. 4. This suggestion offers a modified central heating scheme. There were 4140 answers to this question, some 800 less than those who answered the question about the larger scheme. Of these, 55 per cent said they would like the scheme and 45 per cent said they would not. In the earlier question about the larger scheme, 75 per cent said they would like it.

A 1. 5. 6. 41. *Analysis by Income.* There is no difference in the proportions in the two income groups who would prefer this form of central heating.

A 1. 5. 6. 42. *Analysis by Region.* The analysis of this question by region shows a different trend from that of the question about the larger scheme. In every region the proportion who would like this modified arrangement is less than the proportion who would like the fuller scheme first mentioned (Table 42). The coldest region again has the least proportion (31 per cent) liking the alternative scheme. There is also a considerable difference between Region II, where 43 per cent would like the scheme; Region IV, where 53 per cent would like the scheme; and Region III, where 65 per cent express this preference. Thus the modified scheme was most popular in Region III, whereas the full scheme was most popular in Region IV. It is difficult to account for this difference.

A 1. 5. 6. 43. *Analysis by Urban and Rural Areas.* There was no significant difference between the urban and rural sample in the answers to this question.

A 1. 5. 6. 44. *Analysis by Age.* The analysis by age (Table 43) bears out the general thesis noted early in this Report that preference for central heating is higher in the youngest age-group (66 per cent), and lowest in the two higher age-groups (54 per cent and 55 per cent).

A 1. 5. 6. 45. *Analysis by Old and New Houses.* Unlike the answers to Question 15, there was a considerable difference in the preferences of housewives in new and old houses (Table 44). Whereas 50 per cent of the housewives living in the new houses said they would like hot water, and central heating in their sitting room, 61 per cent of the housewives living in old houses said they would not like this arrangement. It should, perhaps, be mentioned that comments made to the field workers suggest that this larger proportion amongst housewives in old houses is in some measure a reflection of the fact that some considered a limited installation a more practical proposition in relation to old property, than the full scheme which would have meant much structural alteration.

Question 19:

"*If there was a charge in winter months, how much would you be prepared to pay per week?*"

A 1. 5. 6. 5. There were some 3043 answers to this question compared with over 4000 who answered the previous question. Of these over a thousand or one-third were unable to express an opinion. Of the rest, 15 per cent were willing to pay up to 4*s*. 6*d*. a week, 34 per cent up to 3*s*. 6*d*., and 53 per cent up to 2*s*. 6*d*.

A 1. 5. 6. 51. *Analysis by Income.* As in the analysis of Question 16, there is a difference between the two income groups, in so far as the higher income groups are prepared to pay rather more for the service and a less proportion of them are unable to make a decision (Table 45).

19 per cent of the higher income group are prepared to pay up to 4*s*. 6*d*. a week compared with 11 per cent in the lower income group, 40 per cent are prepared to pay up to 3*s*. as compared with 27 per cent, and 57 per cent are prepared to pay up to 2*s*. 6*d*. compared with 48 per cent.

A 1. 5. 6. 52. *Analysis by Degree-Day Region.* The analysis by degree-day region (Table 46) shows a curious feature which has already been noted in the analysis of Question 16, that is that the proportion prepared to pay the highest price is highest in Region III, the warmest but one region, next highest in II and IV, and lowest of all in Region I, the coldest region. Conversely, the proportion not willing to pay anything is highest in Region I, the coldest region (nearly 60 per cent), and lowest in Region III (5 per cent). The willingness to pay for this service is higher in the regions where the proportion of housewives who would like this service is also high. This result is in contrast to the results of the questions about the more comprehensive scheme (Questions 16 and 15), where the proportion liking the scheme was highest in Region IV and the proportion willing to pay most was highest in Region III.

A 1. 5. 6. 53. *Analysis by Urban and Rural Areas.* There is no very great difference between the urban and rural sample on this question.

A 1. 5. 6. 54. *Analysis by Age.* In this analysis it will be seen that the younger housewives are more willing than the older groups to pay something for the service, and also that the younger housewives are prepared to pay more (Table 47).

A 1. 5. 6. 55. *Analysis by Old and New Houses.* Housewives living in old houses were more willing to pay the higher charges of 3*s*. and 4*s*. 6*d*. a week than those living in new houses (Table 48). This result confirms the analysis of the previous question in which a greater proportion of these housewives said they would like this scheme.

Question 20:

"*Would you still like central heating in the sitting room and constant hot water in the kitchen and bathroom if there was no fireplace in your sitting room?*"

A 1. 5. 6. 6. 3455 housewives answered this question, of whom 45 per cent said they would like this arrangement (Table 49). This may be compared with 55 per cent who said they would like a similar arrangement with the fireplace in the sitting room.

An interesting feature of this analysis is that the proportion who would like the modified scheme without the fireplace is slightly higher than the proportion who would like the full scheme without the sitting room fireplace.

A 1. 5. 6. 61. *Analysis by Income.* There is no significant difference between the income groups in this analysis.

A 1. 5. 6. 62. *Analysis by Degree-Day Region.* The regional analysis shows the same pattern as the analysis of Question 18, namely that this modified scheme is preferred most in Region III and least in Region I (Table 49).

A 1. 5. 6. 63. *Analysis by Urban and Rural Areas.* There is no significant difference between the answers of the housewives living in the town compared with those living in the country.

A 1. 5. 6. 64. *Analysis by Age.* In the analysis of this question by age-groups, although there is the same pattern as in previous analyses of central heating questions by age, the difference between the younger group and the two older groups is very much less (Table 50). Roughly half of the youngest age-group would like this

modified central heating scheme without a coal fireplace, as compared with two-fifths in the two older groups.

HOUSEWIVES' OPINIONS ABOUT CENTRALLY HEATING A PART OF THEIR HOUSES

A 1. 5. 7. In Question 21 the housewife was asked, "If it was possible to have part of your house centrally heated which part would you choose?" Question 22 asked "Why?" (Tables 51 A and 51 B).

These two questions have been analysed together and a separate analysis has been made into households with children and households without children.

It should be remembered that the housewife's opinions may in some way have been coloured by the previous questions on the questionnaire, and that her interest in central heating will have been aroused before the question was put, and that she will, in fact, have been thinking about several possible central heating schemes.

4220 housewives answered this section, of whom 45 per cent would prefer their upstairs heated. The next most favoured part of the house is the living room, only 14 per cent. These two categories should be amplified by the addition of two categories which are in many ways their converse. The upstairs might have had added to it the 9·6 per cent who would like any part of the house heated except the living room, and the 14 per cent who prefer the living room centrally heated might have had added to them the 9 per cent who would like any part of the house centrally heated except the bedrooms.

In thus comparing the 55 per cent who would like the bedrooms heated with the 23 per cent who would like the main living room heated, it must be remembered that the fireplace in the living room is the important focal point of all domestic social life, and is thus very dear to the housewife in spite of the labour, and in some cases on account of the labour, associated with it.

A 1. 5. 7. 1. *Comparison of Families with Children and Those Without*

There are only small differences between these groups (Tables 52 A, B, C, and D).

Comparing the proportions who would not have any central heating at all, it will be seen that this is greatest in households without children (14 per cent compared with 9 per cent in households with children).

Houses with children have a higher proportion who favour central heating in the bedrooms (50 per cent compared with 43 per cent). Of the 1149 who prefer to have bedrooms heated, 142 or 12 per cent of the total do so because "children are less likely to catch cold going to bed."

A 1. 6. HOT WATER, BATHING, WASHING, AND LAUNDRY

A 1. 6. 1. The fourth section of the questionnaire was concerned with water heating and allied subjects.

The questions were designed first to discover what methods of water heating were in use (Question 23), what other types had been used (Question 24), what the housewives' opinions of these were (Question 25), and what kind of water heating they liked best (Question 26).

Questions 27 and 28 were designed to find out how much water was used for bathing, and whether more would be used if hot-water arrangements were better or the supply cheaper.

Housewives were then asked if they would like constant hot water laid on and whether they would be prepared to pay for it (Questions 29 and 30). This section was similar in form to the central heating questions.

The laundry section of the questionnaire dealt with clothes-washing habits, with the use made of communal laundries, and also with the use made of commercial laundries and the cost of this service.

WATER HEATING

A 1. 6. 2. Question 23 was divided into two parts and asked how water was heated for baths and for clothes washing. There were some 5243 answers to these questions (Table 53).

Taking the sample as a whole and examining the water heating for baths first, it was found that 30 per cent of all households heated water for baths in pans and kettles on the fire, on the stove, on the range, or on the cooker; 26 per cent of the

households had a fire-back boiler in their kitchen or sitting room fireplace or range with a pipe supply; 15 per cent used the copper or set-pot heated by coal; 10 per cent the gas boiler; and 7 per cent had a gas geyser.

Water was heated for clothes washing in the following ways: in 31 per cent of the households the copper or set-pot was used, in 28 per cent the gas boiler, and in 16 per cent water was heated in pans and kettles on the fire or range.

These total figures have been analysed by income, by age, and by degree-day region, the latter because water heating, like cooking, is in many homes closely associated with space heating.

A 1. 6. 2. 1. *Analysis by Income*

The analysis by income (Table 53) reflects clearly on the higher standard of domestic efficiency which is possible in the higher income group; for example, in the heating of bath water, 30 per cent in the higher income group had a fire-back boiler with pipe supply compared with 20 per cent in the lower income group. Again, 10 per cent in the higher income group had a gas geyser compared with 5 per cent in the lower income group. In contrast to this; 37 per cent of the lower income group households heated their bath water in pans and kettles, etc., compared with 24 per cent in the higher income group.

Water heating for clothes showed the same tendency. Here 20 per cent of the poorer households heated their water for clothes washing in pans and kettles, compared with 12 per cent in the higher income group, the higher income group having a higher proportion with gas boilers and gas geysers.

A 1. 6. 2. 2. *Analysis by Region*

The main point which emerges from the analysis by degree-day region is the fact that in the coldest region there is a much higher proportion of housewives who have fire-back boilers with pipe supply; 65 per cent in the coldest region, 38 per cent in the next, 29 per cent in the next, and 10 per cent in the warmest region. This appears to show that in the colder regions the heating of water and, as has been shown in the cooking section, the cooking of food are more closely bound up with space heating.

A 1. 6. 3. HOUSEWIVES' PREFERENCES FOR WATER HEATING SYSTEMS AND THEIR LIKES AND DISLIKES ABOUT THEM

A 1. 6. 3. 1. The most preferred type of hot-water supply was constant hot water, which was preferred by 39 per cent of the 4248 housewives who were able to express an opinion. The fire-back boiler with pipe supply was chosen by 33 per cent. The only other systems which were favoured by a considerable proportion were the gas geyser and gas storage heater 9 per cent, and the electric immersion heater 8 per cent.

A 1. 6. 3. 2. *Analysis by Degree-Day Region*

This analysis demonstrates again the interrelationship of water heating and space heating. Preference for the fire-back boiler (which implies a fire all the year round) was highest in the coldest region and lower in each of the warmer regions (Table 54). The proportions were as follows:

Region	I.	5000–5500 degree-days	65 per cent
,,	II.	4500–5000 ,,	50 ,,
,,	III.	4000–4500 ,,	41 ,,
,,	IV.	Under 4000 ,,	11 ,,

It should be noted that degree-day Region I has the highest proportion of this type of water heater.

The most important other difference was in the preferences for constant hot water, which were as follows:

Region	I.	5000–5500 degree-days	17 per cent
,,	II.	4500–5000 ,,	31 ,,
,,	III.	4000–4500 ,,	28 ,,
,,	IV.	Under 4000 ,,	56 ,,

This result, which is almost the converse of the other, shows that in the warmer region water heating, separate from space heating, is preferred.

A 1. 6. 3. 3. *Likes and Dislikes about Water Heating Apparatus*

The most important reason for liking the preferred water heating apparatus was in most cases a simple unspecified preference showing that the housewives had no very clear reason for preferring one type of water heater to another, although the handiness of the fire-back boiler and of the gas boiler were mentioned, and these reasons were important for the gas geyser and storage heater, the electric immersion heater, and the electric boiler. Cheapness was most important in the case of the copper or set-pot.

The dislikes about the same set of apparatus were perhaps more revealing. The most disliked apparatus were pans and kettles on the fire, and the copper and set-pot. They were disliked because they made hard work and were inconvenient. Both the fire-back boiler and the range with boiler, but without pipe supply, were also referred to as being hard work and inconvenient in many cases. The gas boiler, gas geyser, and electric immersion heater were all condemned on account of expense by a large proportion of the housewives who had used them.

HOT WATER FOR BATHS

A 1. 6. 4. This section of the inquiry is less satisfactory than the rest. The difficulties arose, on the one hand, from the diffidence of the investigators in asking what they considered to be a personal question and, on the other hand, on the unwillingness of some housewives to answer the question clearly. The form of the question also gave rise to some ambiguity. It had been hoped that the non-personal form, " How many times a week do you use water for baths ? " would have avoided some of these difficulties, but it appeared not to do so.

With these provisos the main result was that information was obtained from about 4512 families, of whom 26 per cent heated water once a week, 20 per cent twice a week, 15 per cent three times a week, and 12 per cent four times a week.

A 1. 6. 4. 1. *Analysis by Family Size*

Family size was clearly one of the factors which caused more water to be heated for baths during the week (Table 55). For example, the proportion heating water four times in a week was 6 per cent in families from 1–3 and 19 per cent in families from 4–7. The larger families had a greater proportion in all the higher categories.

A 1. 6. 4. 2. *Families With and Without Children Compared*

There was likewise a considerable difference in families with children compared to those without (Table 56). The proportion heating water for baths four times a week and more is higher in every case in the homes with children.

A 1 6. 4. 3. *Analysis into Urban and Rural*

Households living in the town appeared to heat water for baths slightly more frequently than households in the country. Differences were very small.

HOUSEHOLDS' ATTITUDE TO IMPROVED BATHING FACILITIES

A 1. 6. 5. Question 28 asked two questions, " Would more baths be taken if they cost less " and " if it was easier to heat the water ? "

In the first case, about 60 per cent of all housewives answered that more baths would be taken if it cost less to heat the water, whereas 68 per cent said more baths would be taken if it was easier to heat the water.

A 1. 6. 5. 1. *Analysis by Degree-Day Regions*

There were some considerable regional differences (Table 57). In all cases the households in the colder region had a very low proportion of " Yes " answers compared with those in the warmer regions, particularly with the warmest region. In the first case, if baths cost less in the coldest region 20 per cent answered " Yes " compared with 73 per cent in the warmest region, and in the second case, if it was easier to heat the water, 37 per cent answered " Yes " compared with 78 per cent. The differences between Region II and Region III were much less.

There are several factors which help to account for this.

In degree-day Region I water heating is very much related to space heating and, further, this region has a greater proportion of households with baths than any other. The proportions were :

Region	I.	5000–5500 degree-days	61 per cent
,,	II.	4500–5000 ,,	43 ,,
,,	III.	4000–4500 ,,	39 ,,
,,	IV.	Under 4000 ,,	43 ,,

The number of times water was heated for baths each week in each household was also higher in Region I.

Region	I.	5000–5500 degree-days	5·3 times per week
,,	II.	4500–5000 ,,	3·7 ,,
,,	III.	4000–4500 ,,	3·0 ,,
,,	IV.	Under 4000 ,,	3·3 ,,

Question 29:

"*Would you like constant hot water laid on in your kitchen and bathroom without central heating?*"

A 1. 6. 6. There were 4815 answers to this question, of which 86·1 per cent were " Yes " and 13·9 per cent were " No." It may be noted that the proportion in favour of this is higher than that favouring hot water plus central heating.

A 1. 6. 6. 1. *Analysis by Age*

The analysis by age showed the same general tendency that has been seen in almost all the other analyses, namely, that the younger groups are more willing to consider improvements than the older (Table 58). 93 per cent of the housewives under 30 would like this arrangement, compared with 81 per cent of those over 50.

A 1. 6. 6. 2. *Analysis by Region*

The analysis by region again shows the same tendency that the colder region, degree-day Region I, is much more conservative than the warmest region, degree-day Region IV (Table 59). It should be noted, however, that this conclusion needs modifying to a small extent by the fact that many of the housewives in degree-day Region I already have hot water laid on from their fire-back boiler, and this may have influenced their answers to this section. (There were 86 of such housewives, whereas the total answering this question was 149 in this region.) The proportions for the four degree-day regions who would like this arrangement were 51 per cent, 82 per cent, 87 per cent, and 92 per cent, going from the coldest to the warmest region.

A 1. 6. 6. 3. *Analysis by Urban and Rural Areas*

There were no important differences in the analysis of housewives living in the town and country.

A 1. 6. 6. 4. *Analysis by Old and New Houses*

The analysis by old and new houses shows that more housewives living in old houses favoured this scheme than those living in new houses (Table 60). This we believe is accounted for by the fact that many housewives living in new houses have satisfactory hot-water arrangements already and were unwilling, therefore, to consider a change.

PAYMENT FOR CONSTANT HOT WATER

A 1. 6. 7. Question 30 asked, " How much would you be prepared to pay per week for constant hot water only ? " There were 3803 answers to this question, of whom 25 per cent were prepared to pay up to 2*s*. 6*d*., 41 per cent up to 2*s*., 62 per cent up to 1*s*. 6*d*., and 8 per cent nothing ; 30 per cent did not know how much they would be prepared to pay.

A 1. 6. 7. 1. *Analysis by Age*

The younger groups were rather more willing to pay and more willing to pay a higher weekly sum than the older groups ; for example, 28 per cent of the under-30's were willing to pay up to 2*s*. 6*d*., compared with 20 per cent of the over-50's (Table 61). The over-50's were also much more uncertain than the younger groups, 39 per cent of them did not know what they would pay, compared with 27 per cent of the under-30 age-group.

A 1. 6. 7. 2. *Analysis by Degree-Day Region*

Differences between the regional proportions are very similar to those found in the analysis of previous questions. The coldest region has the lowest proportion who are willing to pay anything, and in general the housewives are not willing to pay so much as housewives in the warmer region.

5 per cent in Region I are prepared to pay up to 2*s*., 17 per cent in Region II, 30 per cent in Region III, and 25·9 per cent in Region IV. Of those who are not prepared to pay anything, 51 per cent is the proportion in Region I, 11 per cent in Region II, 6 per cent in Region III, and 34 per cent in Region IV. The number who were unable to make a decision was, however, only 7 per cent in Region I, but a little over 30 per cent in the other three regions.

A 1. 6. 7. 3. *Analysis by Old and New Houses*

Analysis by old and new houses showed that slightly more housewives living in new houses were prepared to pay for this service than housewives living in old houses, and a slightly smaller proportion of the former class were prepared to pay the higher fee, although the differences are quite small. This may be related to the fact that expenditure is higher in new houses.

CLOTHES WASHING AND LAUNDRY

A 1. 6. 8. This section is designed to discover housewives' habits in relation to clothes washing, communal laundries, and public laundries.

A 1. 6. 8. 1. *Clothes Washing*

Question 31 asked the simple question, " Do you do all your own washing ? " Of the 5235 housewives who answered this question, 73 per cent did all their washing and 27 per cent did not (Table 62). This result may be compared with the result obtained from another inquiry, June 1942, which is given below. In this analysis (A) is upper class, (B) upper middle class, (C) lower middle and upper working class, (D) lower working class.

Do you send any clothes or linen to the laundry ?

Analysis by Social Group

SOCIAL GROUP	A	B	C	D	TOTAL
Yes	87·6	72·1	47·4	30·4	48·5
No	12·4	27·9	52·6	69·4	51·5
Sample	153	595	1145	1050	3343

A 1. 6. 8. 2. *Analysis by Degree-Day Region*

The degree-day region analysis showed that rather more housewives in the three colder regions did all their washing than those in the warmer region (Table 62).

A 1. 6. 8. 3. *Analysis by Geographical Region*

This analysis shows that more housewives do their own washing in Scotland and the North than in the rest of the regions, the lowest proportion being in London and the South. The following are the proportions :

Scotland	79 per cent
North	78 ,,
Midlands	74 ,,
London and the South	65 ,,
South-West and Wales	74 ,,

A 1. 6. 8. 4. *Analysis by Urban and Rural Districts*

There was a small difference in the analysis between urban and rural housewives, there being slightly more housewives living in rural areas who did all their own washing (Table 63).

A 1. 6. 8. 5. *Analysis by Age*

Age appeared to affect the answers to this question in two ways (Table 64). The youngest and the oldest groups had the lowest proportion who did all their own washing, about 70 per cent, whereas the housewives in the two middle groups had a higher proportion, 75 per cent and 76 per cent.

A 1. 6. 8. 6. *Analysis by Income*

The analysis by income shows clearly that housewives in the higher group sent more of their washing away to be washed (Table 65). The proportion doing all their own washing was 78 per cent in the lower income group, compared with 70 per cent in the higher income group.

COMMUNAL LAUNDRY

A 1. 6. 9. Question 32 asked : " Is there a communal laundry or public wash-house within 10 minutes' walk ? " (Table 66). This service was available to 14 per cent of the nearly 4000 housewives who answered this question. Of these 28 per cent used it for all their washing regularly, 3 per cent for all occasionally, 4 per cent for heavy washing regularly, and 3 per cent for heavy washing occasionally.

A 1. 6. 9. 1. *Analysis by Income*

Where available, communal laundries were used rather more by housewives in the higher income group than in the lower, 16 per cent compared with 13 per cent, and this difference was particularly marked in the group that used a communal laundry for all their clothes regularly (Table 66).

A 1. 6. 9. 2. *Analysis by Family Size*

The larger families, those with from 4–7 in them, used communal laundries considerably more than the smaller families (Table 67).

COMMERCIAL LAUNDRIES

A 1. 6. 10. As has been seen in the result of Question 31, 27 per cent of the sample used laundries.

These housewives were further asked what washing they sent to the laundry and the answers were divided into two groups, " All washing," and " Heavy washing only." 11 per cent sent all their washing and 89 per cent sent " Heavy washing only " (Table 68).

TYPE OF LAUNDRY SERVICE USED

A 1. 6. 11. Question 35 asked whether households used the finished service or the bagwash service. There were 1092 answers to this question, being most of the housewives who sent clothes to the laundry, as is shown in the previous question.

Of these 87 per cent used the finished service and 13 per cent the bagwash. There was no difference in the service used between families of different sizes, but there was a small difference in those families in the higher income group who used the finished service compared with the lower income group, 88 per cent compared with 85 per cent.

EXPENDITURE ON LAUNDRY

A 1. 6. 12. Details of the expenditure on laundry was obtained for almost all the families who used commercial laundries (Table 69). The returns showed that families in the higher income group spend more on laundry than those in the lower income groups, and that there was little difference in the use made of laundries in summer than in winter.

In most cases the expenditure on laundry was less than 3*s*. a week.

PART II. TABLES

Refer to Text
A 1. 2. 2

Table 1

Annual Expenditure in Houses and Flats Analysed by Number of Rooms

Number of Rooms	Average Annual Expenditure in Houses	Number of Cases	Average Annual Expenditure in Flats	Number of Cases
	£ s. d.		£ s. d.	
1	12 9 4	3	15 10 5	28
2	13 15 10	81	16 12 2	203
3	15 11 8	396	18 12 4	258
4	16 6 6	914	18 8 8	169
5	17 8 4	845	21 17 1	38
6	18 9 7	261	23 3 2	13
7	21 16 7	54	18 10 0	2
8 or more	22 15 8	7	—	—
All rooms	16 16 10	2561	18 2 8	711

Refer to Text
A 1. 2. 2

Table 2

Annual Expenditure in Houses and Flats Analysed by Number in Family

Number in Family	Average Annual Expenditure in Houses	Number of Cases	Average Annual Expenditure in Flats	Number of Cases
	£ s. d.		£ s. d.	
1	11 17 10	82	12 8 6	38
2	14 2 10	514	14 19 2	155
3	16 7 7	661	17 12 11	140
4	17 10 4	549	18 13 7	143
5	18 3 11	360	20 8 10	113
6	19 9 8	192	20 0 8	59
7	19 12 7	106	23 16 0	29
8	22 3 6	41	22 15 2	20
9	18 19 1	21	18 8 6	6
10 and over	24 16 1	16	23 19 3	5
All families	16 16 5	2542	18 1 7	708

Refer to Text
A 1. 2. 2

Table 3

Summary of Table 2

Number in Family	Average Annual Expenditure in Houses	Number of Cases	Average Annual Expenditure in Flats	Number of Cases
	£ s. d.		£ s. d.	
1–3	15 3 5	1257	15 16 0	333
4–7	18 4 4	1207	19 18 6	344
8 and over	21 18 3	78	22 2 2	31
All families	16 16 5	2542	18 1 7	708

Refer to Text
A 1. 2. 2. 1

TABLE 4

AVERAGE ANNUAL EXPENDITURE IN HOUSES AND FLATS ANALYSED BY DEGREE-DAY REGIONS

HOUSES COMPARED WITH FLATS										
DEGREE-DAY REGIONS	I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		NATIONAL	
Expenditure	Houses	Flats	Houses	Flats	Houses	Flats	Houses	Flats	Houses	Flats
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Mean Expenditure	16 19 5	18 2 7	16 6 1	16 7 2	16 19 5	19 1 4	16 19 8	18 19 8	16 15 11	18 2 5

Refer to Text
A 1. 2. 3

Table 5 A

Average Annual Expenditure in Houses and Flats of Equal Size, Equal Family, and Equal Income Analysed by Number of Habitable Rooms

HOUSES : INCOME UNDER £160 PER ANNUM

Number in Family		Number of Rooms: 1	2	3	4	5	6	7	8	All Rooms
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
One	Mean Expenditure	—	10 19 10	11 1 6	11 17 1	12 13 0	13 7 8	—	—	11 16 5
	No. of Cases	—	*12*	*11*	*34*	*11*	*5*	—	—	*73*
Two	Mean Expenditure	14 2 0	13 14 7	13 10 9	13 7 2	13 10 2	15 4 7	16 1 0	—	13 11 1
	No. of Cases	*1*	*19*	*80*	*116*	*82*	*13*	*1*	—	*312*
Three	Mean Expenditure	—	14 11 2	14 6 10	15 16 6	16 14 9	16 12 4	21 15 0	19 3 0	15 14 1
	No. of Cases	—	*9*	*56*	*128*	*101*	*22*	*1*	*1*	*318*
Four	Mean Expenditure	3 3 0	14 16 5	16 4 4	16 16 9	16 7 4	17 15 8	—	—	16 10 4
	No. of Cases	*1*	*7*	*44*	*76*	*69*	*20*	—	—	*217*
Five	Mean Expenditure	—	15 12 5	17 5 10	17 4 4	17 4 7	19 6 11	13 5 6	—	17 7 0
	No. of Cases	—	*4*	*21*	*49*	*43*	*14*	*2*	—	*133*
Six	Mean Expenditure	—	16 4 0	17 13 10	19 12 5	18 7 5	18 9 2	15 17 0	—	18 5 4
	No. of Cases	—	*5*	*10*	*14*	*26*	*9*	*3*	—	*67*
Seven	Mean Expenditure	—	—	11 8 6	17 1 5	17 13 10	21 10 0	13 12 0	—	17 0 5
	No. of Cases	—	—	*2*	*14*	*14*	*1*	*1*	—	*32*
Eight and Over	Mean Expenditure	—	—	25 16 0	17 9 0	17 16 4	23 7 7	28 16 0	—	20 7 11
	No. of Cases	—	—	*1*	*1*	*10*	*5*	*1*	—	*18*

Note.—Figures in italics denote the number of cases from which each mean expenditure is derived.

Refer to Text
A 1. 2. 3

Table 5 B

Average Annual Expenditure in Houses and Flats of Equal Size, Equal Family, and Equal Income Analysed by Number of Habitable Rooms

HOUSES : INCOME OVER £160 PER ANNUM

Number in Family		Number of Rooms: 1	2	3	4	5	6	7	8	9	All Rooms
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
One	Mean Expenditure	—	—	—	12 5 0	10 15 4	19 17 0	—	—	—	12 2 1
	No. of Cases	—	—	—	*2*	*6*	*1*	—	—	—	*9*
Two	Mean Expenditure	—	13 0 4	14 1 0	15 4 7	15 2 6	15 2 5	20 9 5	—	—	15 0 11
	No. of Cases	—	*10*	*27*	*75*	*63*	*22*	*5*	—	—	*202*
Three	Mean Expenditure	20 3 0	14 10 11	16 6 1	16 0 4	17 7 7	18 8 1	19 2 2	25 10 0	—	16 17 0
	No. of Cases	*1*	*7*	*59*	*122*	*103*	*35*	*12*	*1*	—	*340*
Four	Mean Expenditure	—	13 13 4	18 13 10	17 5 2	18 4 2	19 5 1	23 13 5	23 7 0	—	18 3 10
	No. of Cases	—	*4*	*40*	*119*	*109*	*49*	*9*	*1*	—	*331*
Five	Mean Expenditure	—	18 1 4	17 10 1	18 4 4	19 1 0	19 10 0	22 13 7	—	—	18 13 10
	No. of Cases	—	*3*	*24*	*78*	*92*	*27*	*3*	—	—	*227*
Six	Mean Expenditure	—	—	14 16 8	19 16 10	19 18 6	22 1 1	27 0 6	—	29 7 0	20 3 4
	No. of Cases	—	—	*9*	*48*	*47*	*13*	*6*	—	*1*	*124*
Seven	Mean Expenditure	—	—	18 2 10	19 13 7	21 15 10	19 19 6	26 18 0	21 2 0	—	20 15 2
	No. of Cases	—	—	*8*	*18*	*31*	*13*	*3*	*1*	—	*74*
Eight and Over	Mean Expenditure	—	—	18 11 9	20 17 9	23 4 0	21 10 0	24 2 5	20 10 6	—	22 7 4
	No. of Cases	—	—	*3*	*11*	*30*	*7*	*7*	*2*	—	*60*

Note.—Figures in italics denote the number of cases from which each mean expenditure is derived.

TABLE 5 C

ANNUAL EXPENDITURE IN HOUSES AND FLATS OF EQUAL SIZE, EQUAL FAMILY, AND EQUAL INCOME ANALYSED BY NUMBER OF HABITABLE ROOMS

FLATS : INCOME UNDER £160 PER ANNUM

NUMBER IN FAMILY		NUMBER OF ROOMS: 1	2	3	4	5	6	7	8	9	All Rooms
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
ONE	Mean Expenditure	10 13 0	12 14 10	11 7 5	13 15 10	—	—	—	—	—	12 5 5
	No. of Cases	*4*	*16*	*11*	*6*	—	—	—	—	—	*37*
TWO	Mean Expenditure	17 11 4	13 19 4	15 13 7	16 18 8	13 12 0	—	—	—	—	15 3 11
	No. of Cases	*8*	*47*	*37*	*13*	*1*	—	—	—	—	*106*
THREE	Mean Expenditure	13 16 4	16 8 1	17 11 11	18 13 6	20 2 0	—	—	—	—	17 9 0
	No. of Cases	*3*	*13*	*20*	*13*	*2*	—	—	—	—	*51*
FOUR	Mean Expenditure	—	17 17 7	20 15 4	17 19 4	22 9 6	13 11 0	—	—	—	19 5 3
	No. of Cases	—	*12*	*21*	*12*	*2*	*1*	—	—	—	*48*
FIVE	Mean Expenditure	14 2 0	19 4 11	21 2 0	20 8 3	22 15 4	—	—	—	—	20 3 5
	No. of Cases	*3*	*8*	*15*	*16*	*3*	—	—	—	—	*45*
SIX	Mean Expenditure	—	18 19 0	18 2 7	17 3 6	—	17 8 0	—	—	—	18 1 10
	No. of Cases	—	*7*	*5*	*6*	—	*1*	—	—	—	*19*
SEVEN	Mean Expenditure	—	16 0 0	—	19 4 0	—	—	—	—	—	17 12 0
	No. of Cases	—	*1*	—	*1*	—	—	—	—	—	*2*
EIGHT AND OVER	Mean Expenditure	—	—	—	27 17 0	22 14 0	22 13 0	—	—	—	24 18 0
	No. of Cases	—	—	—	*3*	*3*	*1*	—	—	—	*7*

Note.—Figures in italics denote the number of cases from which each mean expenditure is derived.

Refer to Text
A 1. 2. 3

Table 5 D

Annual Expenditure in Houses and Flats of Equal Size, Equal Family, and Equal Income Analysed by Number of Habitable Rooms

FLATS: INCOME OVER £160 PER ANNUM

Number in Family		Number of Rooms: 1	2	3	4	5	6	7	8	9	All Rooms
		£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
One	Mean Expenditure	—	—	—	18 3 0	—	—	—	—	—	18 3 0
	No. of Cases	—	—	—	*1*	—	—	—	—	—	*1*
Two	Mean Expenditure	15 19 0	13 12 10	14 7 2	16 2 10	—	—	—	—	—	14 9 1
	No. of Cases	*2*	*20*	*18*	*9*	—	—	—	—	—	*49*
Three	Mean Expenditure	16 5 0	18 19 6	18 6 4	16 5 5	16 8 11	—	—	—	—	17 15 10
	No. of Cases	*2*	*24*	*33*	*22*	*7*	—	—	—	—	*88*
Four	Mean Expenditure	13 1 0	17 18 2	19 14 8	17 3 8	21 4 4	—	—	—	—	18 9 0
	No. of Cases	*2*	*20*	*39*	*29*	*3*	—	—	—	—	*93*
Five	Mean Expenditure	19 12 0	19 18 0	21 3 11	19 13 8	24 3 5	—	—	—	—	20 12 4
	No. of Cases	*3*	*15*	*22*	*22*	*6*	—	—	—	—	*68*
Six	Mean Expenditure	—	20 9 2	20 3 2	24 10 1	26 13 2	—	—	—	—	21 19 6
	No. of Cases	—	*10*	*16*	*10*	*4*	—	—	—	—	*40*
Seven	Mean Expenditure	—	20 14 6	26 4 11	20 2 10	24 10 0	26 18 5	—	—	—	24 5 2
	No. of Cases	—	*4*	*8*	*4*	*6*	*5*	—	—	—	*27*
Eight and Over	Mean Expenditure	18 8 0	21 0 4	21 16 11	21 16 5	17 15 0	22 11 0	18 10 0	—	—	21 6 0
	No. of Cases	*1*	*3*	*10*	*2*	*1*	*5*	*2*	—	—	*24*

Note.—Figures in italics denote the number of cases from which each mean expenditure is derived.

Refer to Text
A 1. 2. 5
A 1. 2. 5. 1

TABLE 6
COAL CLUB MEMBERSHIP
ANALYSED BY INCOME

CLUB MEMBERSHIP	UNDER £150 PER ANNUM		OVER £150 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%
YES	160	7	162	6	322	6
NO	2102	93	2547	94	4649	94
ALL	2262	100	2709	100	4971	100

Refer to Text
A 1. 2. 6

TABLE 7
COST OF COAL PER CWT.
ANALYSED BY URBAN AND RURAL AREAS

PRICE PER CWT.	URBAN		RURAL		TOTAL	
	No.	%	No.	%	No.	%
Special Prices	63	2	9	1	72	2
1/10–2/2	402	9	12	1	414	8
2/3 –2/7	1400	32	246	33	1646	32
2/8 –3/–	1173	27	181	25	1354	27
3/1 –3/5	1091	25	233	32	1324	26
3/6 –3/10	214	5	50	7	264	5
3/11–4/3	13	—	3	—	16	—
4/4 –4/8	9	—	5	1	14	—
4/9 –5/–	3	—	1	1	4	—
TOTAL	4368	100	740	100	5108	100

Refer to Text
A 1. 2. 6

TABLE 8
COST OF COAL PER CWT.
ANALYSED BY GEOGRAPHICAL REGIONS

PRICE PER CWT.	SCOTLAND		NORTH		MIDLANDS		LONDON, ETC.		SOUTH-WEST AND WALES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Special Prices	6	1	33	2	14	2	1	—	19	3
1/11–2/2	38	5	309	20	52	7	2	—	16	2
2/3 –2/7	278	37	1000	63	275	38	12	1	87	12
2/8 –3/–	347	47	232	14	320	44	98	8	369	50
3/1 –3/5	58	8	8	1	60	9	977	77	152	21
3/6 –3/10	12	1	2	—	—	—	173	13	78	11
3/11–4/3	2	—	1	—	1	—	9	1	3	—
4/4 –4/8	4	1	—	—	—	—	—	—	10	1
4/9 –5/–	—	—	1	—	1	—	2	—	—	—
TOTAL	745	100	1586	100	723	100	1274	100	734	100

Refer to Text
A 1. 2. 6

TABLE 9

COST OF COAL PER CWT.
ANALYSED BY COALFIELD VERSUS REST
(FOR REGION II ONLY)

PRICE PER CWT.	COALFIELD		REST		TOTAL	
	No.	%	No.	%	No.	%
Special Prices	27	3	5	2	32	3
1/10–2/2	248	29	8	3	256	22
2/3 –2/7	506	59	140	45	646	55
2/8 –3/–	79	9	148	48	227	19
3/1 –3/5	2	—	6	2	8	1
3/6 –3/10	1	—	1	—	2	—
3/11–4/3	—	—	1	—	1	—
4/4 –4/8	—	—	—	—	—	—
4/9 –5/–	1	—	1	—	2	—
TOTAL	864	100	310	100	1174	100

Refer to Text
A 1. 2. 7

TABLE 10

AMOUNT OF COAL PURCHASED AT ONE TIME
URBAN AND RURAL DISTRICTS COMPARED

AMOUNT OF COAL PURCHASED	URBAN		RURAL		TOTAL	
	No.	%	No.	%	No.	%
1 cwt.	610	14	115	16	725	14
2 cwt.	1567	36	277	38	1844	36
3 cwt.	726	17	104	14	830	16
4 cwt.	186	4	31	4	217	4
5 cwt.	419	10	86	12	505	10
5–10 cwt.	417	10	46	6	463	9
10–20 cwt.	358	8	54	8	412	8
Over 20 cwt.	62	1	8	1	70	1
None	9	—	—	—	9	—
TOTAL	4354	100	721	100	5075	100

Refer to Text
A 1. 2. 7. 1

TABLE 11

QUANTITY OF COAL PURCHASED AT ONE TIME ANALYSED IN RELATION TO CELLAR CAPACITY

CELLAR CAPACITY	QUANTITIES PURCHASED																										
	1 CWT.			2 CWT.			3 CWT.			4 CWT.			5 CWT.			5–10 CWT.			10–20 CWT.			OVER 20 CWT.			TOTAL CASES		
	No.	%	%	No.	%	%	No.	%	%	No.	%	%	No.	%	%	No.	%	%	No.	%	%	No.	%	%	No.	%	%
1 cwt.	30	6	81	5	—	14	2	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	37	1	100
2 cwt.	27	5	20	97	7	74	6	1	5	—	—	—	1	—	—	—	—	—	1	—	1	—	—	—	132	4	100
3 cwt.	31	6	20	67	5	44	53	9	35	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	152	4	100
4 cwt.	25	5	17	63	5	44	39	6	27	16	10	11	1	—	1	—	—	—	—	—	—	—	—	—	144	4	100
5 cwt.	83	16	26	121	9	38	53	9	17	14	8	4	44	12	14	3	1	1	—	—	—	—	—	—	318	9	100
5–10 cwt.	129	25	16	309	23	38	136	22	17	38	23	5	106	28	13	94	26	12	1	—	—	2	4	—	815	22	100
10–20 cwt.	110	22	9	432	32	36	203	33	17	57	34	5	142	38	12	148	41	12	120	37	10	2	4	—	1214	32	100
Over 20 cwt.	77	15	8	243	18	26	121	20	13	42	25	5	81	22	9	114	32	12	202	62	22	53	93	6	933	25	100
TOTAL	512	100	14	1337	100	36	613	100	16	168	100	5	375	100	10	359	100	10	324	100	9	57	100	2	3745	100	100

Refer to Text
A 1. 2. 7. 2

TABLE 12

REASONS FOR PURCHASING COAL ANALYSED BY QUANTITY PURCHASED AT ONE TIME

REASONS	QUANTITIES																	
	1 CWT.		2 CWT.		3 CWT.		4 CWT.		5 CWT.		5–10 CWT.		10–20 CWT.		20 CWT.		TOTAL CASES	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
All one can have	167	24	462	26	190	24	38	19	106	22	53	12	18	5	2	3	1036	21
What one needs	172	24	626	35	310	39	93	47	136	29	95	22	76	20	7	11	1515	32
Can't afford more	253	36	420	24	166	21	25	13	37	8	16	4	10	3	2	3	929	19
Cheaper	7	1	6	—	6	1	1	—	37	8	63	15	57	15	16	25	193	4
Capacity of coal-shed	41	6	109	6	55	7	12	6	36	8	42	10	42	11	8	13	345	7
Easier	36	5	78	5	26	3	14	7	55	12	74	17	74	19	8	13	365	8
Can't get less	1	—	4	—	3	—	1	—	17	3	11	3	9	2	2	3	48	1
Like a stock	28	4	72	4	42	5	9	5	47	10	69	16	56	15	12	19	335	7
Colliery and Trade Allowance	—	—	3	—	1	—	7	3	2	—	6	1	38	10	6	10	63	1
TOTAL	705	100	1780	100	799	100	200	100	473	100	429	100	380	100	63	100	4829	100

Refer to Text
A 1. 3. 2
A 1. 3. 2. 1

TABLE 13

TYPE OF FUEL USED FOR COOKING IN WINTER ANALYSED BY GEOGRAPHICAL REGIONS

FUEL	SCOTLAND		NORTH		MIDLANDS		LONDON AND S.		S.W. AND WALES		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Coal	381	50	1094	67	336	45	494	36	411	54	2716	52
Gas	578	76	1180	72	557	75	1048	77	447	59	3810	72
Electricity	75	10	111	7	89	12	147	11	59	8	481	9
Oil	43	6	12	1	1	—	39	3	49	6	144	3
SAMPLE	757	100	1635	100	742	100	1369	100	764	100	5267	100

Refer to Text
A 1. 3. 2
A 1. 3. 2. 1

TABLE 14

TYPE OF FUEL USED FOR COOKING IN SUMMER ANALYSED BY GEOGRAPHICAL REGIONS

FUEL	SCOTLAND		NORTH		MIDLANDS		LONDON AND S.		S.W. AND WALES		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Coal	248	33	954	58	182	25	125	9	295	39	1804	34
Gas	577	76	1221	75	589	79	1126	82	464	61	3977	76
Electricity	75	10	119	7	92	12	151	11	67	9	504	10
Oil	44	6	14	1	2	—	44	3	61	8	165	3
SAMPLE	757	100	1635	100	742	100	1369	100	764	100	5267	100

Refer to Text
A 1. 3. 2. 2
A 1. 3. 2. 3

TABLE 15

COAL USERS USING OTHER FORMS OF FUEL FOR COOKING ANALYSED BY URBAN AND RURAL AREAS

WINTER

FUEL	URBAN		RURAL		TOTAL	
	No.	%	No.	%	No.	%
Gas	1421	93	159	51	1580	86
Electricity	100	6	51	16	151	8
Oil	16	1	101	33	117	6
TOTAL	1537	100	311	100	1848	100

Summer

FUEL	URBAN		RURAL		TOTAL	
	No.	%	No.	%	No.	%
Gas	866	92	96	45	962	83
Electricity	65	7	31	15	96	8
Oil	14	1	84	40	98	9
Total	945	100	211	100	1156	100

Refer to Text
A 1. 3. 3

Table 16

Type of Grate Used for Cooking by Solid Fuel

TYPE OF GRATE	NATIONAL	
	No.	%
Open fire with oven only	1623	58
Heats another room (back to back)	82	3
Heats water in boiler	261	10
Heats water for kitchen sink or bathroom	817	29
Total	2783	100

Refer to Text
A 1. 3. 3. 1

Table 17

Type of Solid-Fuel Grate used for Cooking Analysed by Geographical Regions

	SCOTLAND		NORTH		MIDLANDS		LONDON AND HOME COUNTIES		SOUTH-WEST AND WALES		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
An open fire with oven only	222	59	478	43	204	55	438	84	281	72	1623	58
Heats another room	15	4	51	4	10	2	1	—	5	1	82	3
Heats water in boiler	19	5	114	10	103	28	11	2	15	4	262	10
Heats water for kitchen sink or bathroom	122	32	479	43	57	15	70	14	89	23	817	29
Total	378	100	1122	100	374	100	520	100	390	100	2784	100

Refer to Text
A 1. 3. 5. 1
A 1. 3. 5. 2
A 1. 3. 5. 3
A 1. 3. 5. 4

TABLE 18

LIKES AND DISLIKES FOR VARIOUS KINDS OF COOKING FUELS USED

LIKES	COAL		GAS		ELECTRIC		DISLIKES	COAL		GAS		ELECTRIC	
	No.	%	No.	%	No.	%		No.	%	No.	%	No.	%
Like undefined	557	33	765	28	70	10	Dislike undefined	75	12	77	15	13	6
Cheap and economical	321	19	243	9	205	29	Expensive	151	23	181	34	78	38
Clean	38	2	416	15	513	71	Dirty	179	27	210	40	3	1
Easy, convenient	121	7	665	25	139	19	Inconvenient	217	33	29	6	29	14
Reliable	15	1	68	3	15	2	Unreliable	19	3	33	6	8	4
Cooks better	496	30	148	6	103	14	Cooks badly	27	4	59	11	19	9
Healthy	11	1	5	—	10	1	Slow	43	7	3	1	54	26
Quick	8	—	395	15	34	5	Dislike feature	30	5	36	7	10	5
Likes feature	79	5	54	2	17	2	Dangerous	—	—	29	6	11	5
Used to it	291	17	614	23	16	2	Unhealthy	3	—	19	4	—	—
All who express liking	1663	100	2690	100	719	100	All who express dislike	652	100	525	100	205	100
No liking expressed	3605		2578		4549		No dislike expressed	4616		4743		5063	
SAMPLE	5268		5268		5268		SAMPLE	5268		5268		5268	

Refer to Text
A 1. 3. 6. 2

TABLE 19 B

PREFERENCE FOR TYPE OF COOKING APPARATUS ANALYSED BY HOUSEWIVES' AGE AND INCOME

FUEL	UNDER 30				30–40				40–50				OVER 50			
	UNDER £160		OVER £160		UNDER £160		OVER £160		UNDER £160		OVER £160		UNDER £160		OVER £160	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Coal	54	14	44	10	85	18	117	15	112	24	160	20	269	31	140	25
Gas	184	49	182	43	210	44	363	45	226	48	367	45	411	48	284	50
Electricity	140	37	197	47	177	38	326	40	128	28	284	35	168	20	148	25
Oil	—	—	—	—	—	—	1	—	1	—	3	—	5	1	1	—
TOTAL	378	100	423	100	472	100	807	100	467	100	814	100	853	100	573	100

Refer to Text
A 1. 3. 6. 1

Table 19 A

Preference for Type of Cooking Apparatus Analysed by Housewives' Age

FUEL	UNDER 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Coal	99	12	204	16	272	21	410	29	985	20
Gas	368	46	576	45	594	47	697	49	2235	47
Electricity	341	42	506	39	412	32	318	22	1577	33
Oil	—	—	1	—	4	—	6	—	11	—
Total	808	100	1287	100	1282	100	1431	100	4808	100

Refer to Text
A 1. 3. 6. 3

Table 20

Type of Cooking Apparatus Preferred Analysed by Geographical Regions

TYPE PREFERRED	SCOTLAND		NORTH		MIDLANDS		LONDON, ETC.		SOUTH-WEST AND WALES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Coal	97	14	485	31	124	17	179	14	127	19
Gas	338	48	562	36	357	48	704	54	355	51
Electricity	272	38	510	33	251	35	416	32	209	30
Oil	3	—	2	—	—	—	2	—	3	—
Total	710	100	1559	100	722	100	1301	100	694	100

Refer to Text
A 1. 3. 7
A 1. 3. 7. 1

Table 21

Reasons for Preferring Different Types of Cooking Apparatus Analysed by Age Groups

	Under 30						30–40						40–50						Over 50						All Ages					
	Coal		Gas		Elec.		Coal		Gas		Elec.		Coal		Gas		Elec.		Coal		Gas		Elec.		Coal		Gas		Elec.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Like, unspecified	10	—	36	10	29	9	19	9	44	8	29	6	28	10	54	9	15	4	44	11	78	11	14	4	101	10	212	9	87	5
Clean, economical	24	—	48	13	75	22	48	24	81	14	144	28	73	27	68	11	119	29	74	18	73	10	82	26	219	22	270	12	420	27
Clean	5	—	65	18	232	68	7	4	107	19	359	71	12	4	95	16	276	67	16	4	127	18	225	71	40	4	394	18	1092	69
Easy	15	—	95	26	63	18	19	9	134	23	80	16	22	8	154	26	76	18	37	9	161	23	65	20	93	9	544	24	284	18
Reliable	1	—	4	1	—	—	1	1	18	3	4	1	2	1	21	4	3	1	—	—	10	1	5	2	4	—	53	2	12	1
Cooks better	28	—	25	7	21	6	61	30	34	6	28	6	87	32	29	5	31	8	106	26	29	4	21	7	282	29	117	5	101	6
Healthy	1	—	—	—	6	2	1	—	1	—	10	2	1	—	—	—	15	4	6	1	1	—	10	3	9	1	2	—	41	3
Quick	2	—	42	11	17	5	3	1	96	17	13	3	1	—	92	15	18	4	4	1	68	10	8	3	10	1	298	13	56	4
Likes feature	3	—	14	4	7	2	5	2	19	3	9	2	15	6	14	2	5	1	15	4	11	2	7	2	38	4	58	3	28	2
Used to it	17	—	111	30	6	2	58	28	185	32	13	3	66	24	184	31	5	1	131	32	226	32	5	2	272	27	706	32	29	2
More modern	1	—	4	1	7	2	—	—	4	1	8	2	—	—	7	1	8	2	1	—	6	1	3	1	2	—	21	1	26	2
Other people recommended	1	—	5	1	22	6	1	—	12	2	31	6	2	1	9	2	31	8	3	1	14	2	23	7	7	1	40	2	107	7
Safe	—	—	6	2	14	4	2	1	11	2	7	1	1	—	12	2	3	1	7	2	12	2	3	1	10	—	41	2	27	2
Heats house or room	4	—	1	—	—	—	26	13	3	1	1	—	35	14	3	1	1	—	50	12	4	1	—	—	115	12	11	—	2	—
All who express preference	99	—	368	100	341	100	204	100	576	100	506	100	272	100	594	100	412	100	410	100	697	100	318	100	985	100	2235	100	1577	100

Refer to Text
A 1. 3. 8

Table 22

Influence of Experience on Preference for Type of Cooking Fuel

FUEL PREFERENCE	WHETHER USED	NO.	%
Coal	Yes	852	89
	No	103	11
Gas	Yes	1851	85
	No	340	15
Electricity	Yes	769	49
	No	797	51
Oil	Yes	14	—
	No	—	—
All Fuels	Yes	3486	74
	No	1240	26

100 per cent=All who expressed the preference.

Refer to Text
A 1. 4. 2

Table 23

Number of Rooms Heated (Refers to February and March Conditions)

	NO. OF HOUSE-HOLDS	NO. OF ROOMS	TOTAL NO. OF ROOMS	KITCHEN	KITCHEN SITTING ROOM	SITTING ROOM	BED-ROOM
Kitchen only	321	1	321	321	—	—	—
Kitchen-Sitting Room only	3007	1	3007	—	3007	—	—
Sitting Room only	566	1	566	—	—	566	—
Kit. and Kit. Sit.	59	2	118	59	59	—	—
Kit. and Sit. Room	204	2	408	204	—	204	—
Kit. Sit. and Sit. Room	253	2	506	—	253	253	—
Kit., Kit. Sit. and Sit. Room	8	3	24	8	8	8	—
Bedroom only	3	1	3	—	—	—	3
Bedroom and Kit. Sit.	485	2	970	—	485	—	485
Bedroom and Kit.	41	2	82	41	—	—	41
Bedroom, Kit. and Kit. Sit.	9	3	27	9	9	—	9
Bedroom and Sit. Room	155	2	310	—	—	155	155
Bedroom, Kit. and Sit. Room	42	3	126	42	—	42	42
Bedroom, Kit. Sit. and Sit. Room	57	3	171	—	57	57	57
Kit., Kit. Sit., Sit. Room and Bedroom	58	4	232	58	58	58	58
Total	5268		6871	742	3936	1343	850

ABSTRACT	NO.	%
Households heating one room	3897	74
,, ,, two rooms	1197	23
,, ,, three rooms	116	2
,, ,, four rooms	58	1
Total households	5268	100

Refer to Text
A 1.4.2.1

TABLE 24

NUMBER OF ROOMS HEATED, ANALYSED BY HOUSE, FLAT, AND INCOME
(REFERS TO FEBRUARY-MARCH CONDITIONS)

NO. OF ROOMS	INCOME: £160 PER ANNUM						INCOME: £160–£300 PER ANNUM						ALL INCOMES					
	HOUSE		FLAT		TOTAL		HOUSE		FLAT		TOTAL		HOUSE		FLAT		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1	1444	80	346	72	1790	79	1539	73	347	59	1886	70	2983	76	693	65	3676	74
2	315	17	122	25	437	19	484	23	215	37	699	26	799	20	337	32	1136	23
3	28	2	5	1	33	1	65	3	16	3	81	3	93	2	21	2	114	2
4 and over	13	1	7	2	20	1	27	1	6	1	33	1	40	1	13	1	53	1
TOTAL	1800	100	480	100	2280	100	2115	100	584	100	2699	100	3915	100	1064	100	4979	100

Refer to Text
A 1. 4. 3. 1
A 1. 9. 3. 6

TABLE 25

LENGTH OF TIME OF HEATING KITCHEN ON WEEKDAYS IN FEBRUARY AND MARCH ANALYSED BY DEGREE-DAY REGIONS, AND BY URBAN AND RURAL AREAS

	URBAN										RURAL										NATIONAL	
DEGREE-DAY REGIONS	I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		TOTAL		I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		TOTAL			
No. of Hours	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 hour or less	2	—	4	8	2	—	7	17	15	16	—	—	—	—	—	—	—	20	—	20	15	17
1–2 hours	4	—	—		—	—	4		8		—	—	—	—	1	—	1		2		10	
2–4 hours	1	—	2		7	—	7		17		—	—	—	—	1	—	4		5		22	
4–8 hours	2	—	5		8	—	18		33		—	—	10	—	5	—	17		32		65	
8–10 hours	—	—	12	9	4	—	20	10	36	8	—	—	6	—	1	—	7	6	14	7	50	7
10–12 hours	5	—	19	14	18	—	47	23	89	19	—	—	12	—	4	—	18	17	34	17	123	19
12–14 hours	1	—	52	39	22	—	66	32	141	30	—	—	24	—	6	—	41	38	71	36	212	32
14–16 hours	7	—	29	22	22	—	23	11	81	18	—	—	13	—	—	—	16	15	29	14	110	17
16 hours	2	—	10	8	11	—	17	8	40	9	—	—	8	—	—	—	4	4	12	6	52	8
TOTAL	24	—	133	100	94	—	209	100	460	100	—	—	73	—	18	—	108	100	199	100	659	100

Refer to Text
A 1. 4. 3. 2
A 1. 4. 3. 7

Table 26

Length of Time Kitchen-Sitting Room is Heated on Weekdays in February and March Analysed by Degree-Day Regions, and by Urban and Rural Areas

	Urban										Rural										National	
Degree-Day Regions	I 5000–5500		II 4500–5000		III 4000–4500		IV Under 4000		Total		I 5000–5500		II 4500–5000		III 4000–4500		IV Under 4000		Total			
No. of Hours	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 hour or less	—	—	1		3		4		8		—	—	—	—	—		1	—	1		9	
1–2 hours	—	—	1	1	3	1	3	3	7	1	—	—	—	—	—	1	—	—	—	1	7	1
2–4 hours	—	—	3		8		20		31		—	—	1	—	2		1	—	4		35	
4–8 hours	2	—	19	3	27	2	69	6	117	3	—	—	4	2	7	4	4	—	15	3	132	3
8–10 hours	2	—	30	4	82	6	110	10	224	7	—	—	18	7	9	6	6	—	33	7	257	7
10–12 hours	15	—	116	15	232	17	267	24	630	19	—	—	67	28	32	21	24	—	123	25	753	20
12–14 hours	34	—	297	39	429	32	457	42	1217	37	—	—	95	39	47	31	40	—	182	37	1399	37
14–16 hours	24	—	221	29	373	27	131	12	749	23	—	—	47	20	50	33	13	—	110	23	859	23
16 hours	16	—	65	9	207	15	32	3	320	10	—	—	9	4	6	4	2	—	17	3	337	9
Total	93	—	753	100	1364	100	1093	100	3303	100	—	—	241	100	153	100	91	—	485	100	3788	100

Refer to Text
A 1. 4. 3. 3
A 1. 4. 3. 8

Table 27

Length of Time Sitting Room is Heated on Weekdays in February and March Analysed by Degree-Day Regions, and by Urban and Rural Areas

DEGREE-DAY REGIONS	URBAN										RURAL										NATIONAL	
	I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		TOTAL		I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		TOTAL			
No. of Hours	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 hour or less	2	—	4		12		17		35		—	—	2	—	3	—	2	—	7		42	
1–2 hours	—	—	6	7	7	12	7	12	20	11	—	—	5	—	1	—	—	—	6	13	26	11
2–4 hours	2	—	6		19		26		53		—	—	7	—	1	—	5	—	13		66	
4–8 hours	3	—	23	10	26	9	65	16	117	12	—	—	10	—	4	—	19	—	33	17	150	12
8–10 hours	—	—	15	7	32	11	48	11	95	9	—	—	12	—	5	—	11	—	28	14	123	10
10–12 hours	12	—	39	17	46	15	82	20	179	18	—	—	14	—	3	—	27	—	44	23	223	19
12–14 hours	24	—	61	27	91	30	116	28	292	29	—	—	15	—	11	—	24	—	50	26	342	29
14–16 hours	9	—	47	21	44	15	41	10	141	14	—	—	4	—	2	—	4	—	10	5	151	13
16 hours	6	—	26	11	24	8	11	3	67	7	—	—	3	—	—	—	—	—	3	2	70	6
TOTAL	58	—	227	100	301	100	413	100	999	100	—	—	72	—	30	—	92	—	194	100	1193	100

Refer to Text
A 1. 4. 3. 4
A 1. 4. 3. 9

Table 28

Length of Time Bedroom is Heated on Weekdays in February and March Analysed by Degree-Day Regions, and by Urban and Rural Areas

	Urban										Rural										National	
Degree-Day Regions	I 5000–5500		II 4500–5000		III 4000–4500		IV Under 4000		Total		I 5000–5500		II 4500–5000		III 4000–4500		IV Under 4000		Total			
No. of Hours	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Unheated	113	75	862	85	1377	84	1399	90	3751	86	—	—	291	87	153	90	206	90	650	89	4401	87
1 hour or less	13	8	72	7	94	6	59	4	238	5	—	—	23	7	7	4	13	6	43	6	281	6
1–2 hours	8	5	19	2	48	3	38	3	113	3	—	—	6	2	5	3	4	2	15	2	128	3
2–4 hours	12	8	27	3	46	3	15	1	100	2	—	—	8	2	1	1	1	—	10	2	110	2
4–8 hours	4	3	15	2	29	2	10	1	58	1	—	—	5	2	—	—	4	2	9	1	67	1
8–10 hours	—	—	7	1	9	—	4	—	20	1	—	—	—	—	—	—	—	—	—	—	20	—
10–12 hours	—	—	4	—	6	—	11	1	21	1	—	—	—	—	—	—	1	—	1	—	22	—
12–14 hours	—	—	2	—	10	1	8	—	20	1	—	—	1	—	—	—	—	—	1	—	21	—
14–16 hours	—	—	1	—	5	—	2	—	8	—	—	—	—	—	1	1	1	—	2	—	10	—
16 hours	1	1	3	—	12	1	5	—	21	—	—	—	—	—	2	1	—	—	2	—	23	1
Total	151	100	1012	100	1636	100	1551	100	4350	100	—	—	334	100	169	100	230	100	733	100	5083	100

Refer to Text
A 1. 4. 5. 1

Table 29

Length of Time Sitting Room was Heated and by what Fuel on Weekdays and Sundays in February and March

NUMBER OF HOURS	WEEKDAYS										SUNDAYS									
	COAL		GAS		ELEC.		OIL		ALL FUELS		COAL		GAS		ELEC.		OIL		ALL FUELS	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 hour or less	22	2	5	—	13	—	2	—	42	4	13	1	6	—	10	—	2	—	31	2
1–2 hours	17	2	5	—	3	—	1	—	26	2	17	1	5	—	5	—	—	—	27	2
2–4 hours	58	5	2	—	6	—	1	—	67	5	38	3	—	—	5	—	2	—	45	3
4–8 hours	142	12	2	—	3	—	3	—	150	12	213	16	4	—	2	—	2	—	221	16
8–10 hours	123	11	1	—	—	—	1	—	125	11	226	17	2	—	3	—	1	—	232	16
10–12 hours	222	20	—	—	2	—	—	—	224	19	393	29	1	—	3	—	—	—	397	28
12–14 hours	341	30	—	—	1	—	2	—	344	29	320	23	—	—	2	—	2	—	324	23
14–16 hours	150	13	—	—	1	—	—	—	151	13	89	6	—	—	—	—	—	—	89	6
16 hours	62	5	1	—	—	—	—	—	63	5	56	4	1	—	—	—	—	—	57	4
Total	1137	100	16	—	29	—	10	—	1192	100	1365	100	19	—	30	—	9	—	1423	100

Refer to Text
A 1. 4. 5. 2

Table 30

Length of Time Bedroom was Heated and by what Fuel on Weekdays and Sundays in February and March

Number of Hours	Weekdays										Sundays									
	Coal		Gas		Elec.		Oil		All Fuels		Coal		Gas		Elec.		Oil		All Fuels	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 hour or less	73	23	65	62	123	60	20	—	281	41	71	21	62	61	122	61	19	—	274	40
1–2 hours	48	15	24	23	43	21	12	—	127	19	47	14	24	24	43	21	12	—	126	18
2–4 hours	65	20	8	8	31	15	7	—	111	16	63	19	8	8	28	14	6	—	105	15
4–8 hours	52	16	4	4	3	2	8	—	67	10	57	17	4	4	2	1	9	—	72	11
8–10 hours	18		—		2		—	—	20	3	21		—		2		—	—	23	3
10–12 hours	20		—		1		1	—	22	3	29		1		1		1	—	32	5
12–14 hours	14	26	3	3	2	2	2	—	21	3	18	29	2	3	3	3	2	—	25	4
14–16 hours	10		—		—		—	—	10	2	9		—		—		—	—	9	1
16 hours	23		—		—		—	—	23	3	21		—		—		—	—	21	3
Total	323	100	104	100	205	100	50	—	682	100	336	100	101	100	201	100	49	—	687	100
Total over 8 hours	85	89	3	2	5	5	3	—	96	100	98	89	3	3	6	5	3	—	110	100
Total less than 8 hours	238	41	101	17	200	34	47	—	586	100	238	41	98	17	195	34	46	—	577	100

Refer to Text
A 1. 5. 4
A 1. 5. 4. 1

Table 31

Likes and Dislikes about Central Heating Analysed by Degree-Day Regions

Likes and Dislikes	Region I 5000–5500		Region II 4500–5000		Region III 4000–4500		Region IV Under 4000		National	
	No.	%	No.	%	No.	%	No.	%	No.	%
Likes										
Prefer it	30	20	293	21	337	19	678	36	1338	26
Clean and easy	8	5	61	4	91	5	62	3	222	4
Economical	—	—	2	—	3	—	3	—	8	—
Keeps whole house warm	3	2	23	2	39	2	38	2	103	2
Healthy	2	1	33	2	42	2	19	1	96	2
Total Likes	43	28	412	29	512	28	800	43	1767	34
Neutral										
Couldn't say	39	26	478	34	740	42	569	31	1826	35
No objection	5	4	154	11	136	8	153	8	448	9
All right	—	—	14	1	6	—	7	—	27	—
Total Neutral	44	30	646	46	882	50	729	39	2301	44
Dislikes										
Don't like	22	14	117	8	129	7	106	6	374	7
Expensive	—	—	3	—	4	—	7	—	14	—
Cheerless	30	20	159	11	155	9	95	5	439	9
Unreliable	2	1	10	1	19	1	15	1	46	1
Unhealthy	9	6	52	4	66	4	84	5	211	4
Total Dislikes	63	41	341	24	373	21	307	17	1084	21
Miscellaneous	2	1	11	1	11	1	11	1	35	1
Total	152	100	1410	100	1778	100	1847	100	5187	100

Refer to Text
A 1. 5. 5

Table 32

Have You Had Any Direct Experience of Central Heating? Analysed by Income Groups

Answer	Income below £160 per annum		Income £160–£300 per annum		All Incomes	
	No.	%	No.	%	No.	%
Yes	759	32	976	35	1735	34
No	1608	68	1832	65	3440	66
Total	2367	100	2808	100	5175	100

Refer to Text
A 1. 5. 5. 1

Table 33

Likes and Dislikes about Central Heating
Analysed by Age-Groups in Classes of People With and Without Experience of Central Heating

LIKES AND DISLIKES	EXPERIENCE OF CENTRAL HEATING										NO EXPERIENCE OF CENTRAL HEATING											
	UNDER 30		30–40		40–50		OVER 50		TOTAL		UNDER 30		30–40		40–50		OVER 50		TOTAL		FINAL TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Likes																						
Prefer it	113	38	183	39	186	40	158	35	640	38	119	23	190	22	194	22	187	18	690	21	1330	27
Clean and easy	18	6	27	6	24	5	31	7	100	6	14	3	31	3	37	4	27	3	109	3	209	4
Economical	—	—	—	—	1	—	1	—	2	—	—	—	—	—	1	—	1	—	2	—	4	—
Keeps whole house warm	19	7	32	7	21	4	25	6	97	6	18	3	14	2	23	3	22	2	77	3	174	3
Healthy	1	—	3	1	1	—	2	—	7	—	3	1	—	—	2	—	2	—	7	—	14	—
Total Likes	151	51	245	53	233	51	217	48	846	50	154	30	235	27	257	29	239	23	885	27	1731	35
Neutral																						
Couldn't say	45	15	67	14	77	16	75	16	264	16	233	45	381	44	390	44	480	45	1484	45	1748	35
No objections	27	9	38	8	38	8	56	12	159	10	43	8	70	8	75	9	89	8	277	9	436	9
All right	4	2	—	—	—	—	2	—	6	—	1	—	8	1	3	—	6	1	18	—	24	—
Total Neutral	76	26	105	22	115	25	133	29	429	26	277	53	459	53	468	53	575	54	1779	54	2208	44
Dislikes																						
Don't like it	18	6	30	7	30	6	41	9	119	7	24	4	55	6	59	7	102	10	240	7	359	7
Expensive	—	—	—	—	3	1	3	1	6	1	—	—	2	—	3	—	3	—	8	—	14	—
Cheerless	21	7	39	8	31	7	24	5	115	7	47	9	76	9	74	8	102	10	299	9	414	8
Unreliable	3	1	3	1	9	2	7	1	22	1	6	1	4	1	4	1	7	1	21	1	43	1
Unhealthy	21	7	38	8	36	8	22	5	117	7	15	3	27	3	20	2	22	2	84	2	201	4
Total Dislikes	63	21	110	24	109	24	97	21	379	23	92	17	164	19	160	18	236	23	652	19	1031	21
Miscellaneous	4	2	5	1	3	—	5	1	17	1	2	—	6	1	2	—	5	—	15	—	32	1
FINAL TOTAL	294	100	465	100	460	100	452	100	1671	100	525	100	864	100	887	100	1055	100	3331	100	5002	100

Refer to Text
A 1. 5. 6. 11

TABLE 34

WOULD YOU LIKE CENTRAL HEATING IN ALL YOUR ROOMS AND CONSTANT HOT WATER IN YOUR KITCHEN AND BATHROOM? ANALYSED BY AGE-GROUPS

ANSWER	UP TO 30		30–40		40–50		OVER 50		ALL AGE-GROUPS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	640	80	995	77	982	76	967	68	3584	75
No	158	20	294	23	305	24	456	32	1213	25
TOTAL	798	100	1289	100	1287	100	1423	100	4797	100

Refer to Text
A 1. 5. 6. 1
A 1. 5. 6. 1

TABLE 35

WOULD YOU LIKE CENTRAL HEATING IN ALL YOUR ROOMS AND CONSTANT HOT WATER IN YOUR KITCHEN AND BATHROOM? ANALYSED BY DEGREE-DAY REGIONS

ANSWER	I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		ALL REGIONS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	66	45	940	71	1291	74	1427	80	3724	75
No	82	55	379	29	452	26	347	20	1260	25
TOTAL	148	100	1319	100	1743	100	1774	100	4984	100

Refer to Text
A 1. 5. 6. 14

TABLE 36

WOULD YOU LIKE CENTRAL HEATING IN ALL YOUR ROOMS AND CONSTANT HOT WATER IN YOUR KITCHEN AND BATHROOM? ANALYSED BY GEOGRAPHICAL REGIONS

ANSWER	SCOTLAND		NORTH		MIDLANDS		LONDON		SOUTH-WEST AND WALES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	507	74	1048	68	556	78	1046	80	566	76
No	177	26	489	32	152	22	266	20	175	24
TOTAL	684	100	1537	100	708	100	1312	100	741	100

Refer to Text
A 1. 5. 6. 15

TABLE 37

WOULD YOU LIKE CENTRAL HEATING IN ALL YOUR ROOMS AND CONSTANT HOT WATER IN YOUR KITCHEN AND BATHROOM? ANALYSED BY URBAN AND RURAL AREAS

ANSWER	URBAN		RURAL		TOTAL	
	No.	%	No.	%	No.	%
Yes	3217	76	486	69	3703	75
No	1043	24	214	31	1257	25
TOTAL	4260	100	700	100	4960	100

Refer to Text
A 1. 5. 6. 2
A 1. 5. 6. 21

TABLE 38

HOW MUCH WOULD YOU BE PREPARED TO PAY IN THE WINTER MONTHS FOR CENTRAL HEATING TO ALL ROOMS AND CONSTANT HOT WATER TO BATHROOM AND KITCHEN? ANALYSED BY INCOME GROUPS

WEEKLY AMOUNTS	BELOW £160		£160–£300		ALL INCOMES	
	No.	%	No.	%	No.	%
1. Up to 5/–	452	25	874	39	1326	33
2. Up to 3/6 [1]	788	44	1294	58	2082	52
3. Up to 2/6 [1]	1047	58	1569	70	2616	63
4. Nothing	174	10	132	6	306	8
5. Don't know	577	32	534	24	1111	28
TOTAL	1798	100	2235	100	4033	100

Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 22

TABLE 39

IF THERE WAS A CHARGE IN THE WINTER MONTHS, HOW MUCH WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING TO ALL ROOMS AND CONSTANT HOT WATER TO BATHROOM AND KITCHEN? ANALYSED BY DEGREE-DAY REGIONS

WEEKLY AMOUNTS	I 5000–5500		II 4500–5000		III 4000–4500		IV UNDER 4000		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 5/–	22	17	327	33	545	40	435	28	1329	33
Up to 3/6 [1]	46	35	585	49	768	57	787	50	2086	52
Up to 2/6 [1]	58	44	760	66	928	69	973	62	2619	65
Nothing	60	46	95	10	51	4	103	7	309	8
Don't know	14	11	247	25	371	28	484	31	1116	28
TOTAL	132	100	1002	100	1350	100	1560	100	4044	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 24

TABLE 40

IF THERE WAS A CHARGE IN THE WINTER MONTHS, HOW MUCH WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING TO ALL ROOMS AND CONSTANT HOT WATER TO BATHROOM AND KITCHEN?
ANALYSED BY AGE-GROUPS

WEEKLY AMOUNTS	UP TO 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 5/–	254	38	381	36	344	32	303	28	1282	33
Up to 3/6 [1]	393	59	587	55	559	52	467	43	2006	51
Up to 2/6 [1]	490	73	744	69	702	65	587	55	2523	65
Nothing	37	6	74	7	86	8	104	10	301	8
Don't know	140	21	256	24	294	27	386	36	1076	28
TOTAL	667	100	1074	100	1082	100	1077	100	3900	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 3
A 1. 5. 6. 32

TABLE 41

WOULD YOU STILL LIKE CENTRAL HEATING IF THERE WERE NO COAL FIREPLACES IN THE HOUSE?
ANALYSED BY DEGREE-DAY REGIONS

ANSWER	REGION I 5500–5000		REGION II 4500–5000		REGION III 4000–4500		REGION IV UNDER 4000		ALL REGIONS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	28	21	422	40	573	41	629	40	1652	40
No	107	79	631	60	829	59	959	60	2526	60
TOTAL	135	100	1053	100	1402	100	1588	100	4178	100

Refer to Text
A 1. 5. 6. 42

Table 42

Would You Like Central Heating in the Sitting Room and Constant Hot Water in the Kitchen and Bathroom? Analysed by Degree-Day Regions

ANSWER	REGION I 5000–5500		REGION II 4500–5000		REGION III 4000–4500		REGION IV UNDER 4000		ALL REGIONS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	44	31	362	43	1012	65	847	53	2265	55
No	98	69	480	57	557	35	740	47	1875	45
Total	142	100	842	100	1569	100	1587	100	4140	100

Refer to Text
A 1. 5. 6. 44

Table 43

Would You Like Central Heating in the Sitting Room and Constant Hot Water in the Kitchen and Bathroom? Analysed by Age-Groups

ANSWER	UP TO 30		30–40		40–50		OVER 50		ALL GROUPS	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	459	66	699	61	643	54	678	55	2479	58
No	232	34	453	39	557	46	557	45	1799	42
Total	691	100	1152	100	1200	100	1235	100	4278	100

Refer to Text
A 1. 5. 6. 45

Table 44

Would You Like Central Heating in the Sitting Room and Constant Hot Water in the Kitchen and Bathroom? Analysed by New and Old Houses

ANSWER	NEW HOUSE		OLD HOUSE		NATIONAL	
	No.	%	No.	%	No.	%
Yes	713	50	1838	61	2551	58
No	708	50	1156	39	1864	42
Total	1421	100	2994	100	4415	100

Refer to Text
A 1. 5. 6. 51

TABLE 45

IF THERE WAS A CHARGE IN THE WINTER MONTHS, WHAT WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN THE KITCHEN AND BATHROOM? ANALYSED BY INCOME GROUPS

WEEKLY AMOUNTS	BELOW £160 PER ANNUM		£160–£300 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%
Up to 4/6	158	11	306	19	464	15
Up to 3/– [1]	382	27	653	40	1035	34
Up to 2/– [1]	662	48	834	57	1596	53
Nothing	224	16	204	12	428	14
Don't know	507	36	505	31	1012	33
TOTAL	1393	100	1643	100	3036	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 52

TABLE 46

IF THERE WAS A CHARGE IN THE WINTER MONTHS, HOW MUCH WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN KITCHEN AND BATHROOM? ANALYSED BY DEGREE-DAY REGIONS

WEEKLY AMOUNTS	REGION I 5000–5500		REGION II 4500–5000		REGION III 4000–4500		REGION IV UNDER 4000		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 4/6	2	2	88	12	255	24	120	11	465	15
Up to 3/– [1]	12	9	213	28	447	41	364	34	1036	34
Up to 2/– [1]	35	27	376	49	639	59	547	51	1597	52
Nothing	76	59	115	15	58	5	182	17	431	14
Don't know	17	13	269	35	387	36	342	32	1015	33
TOTAL	128	100	760	100	1084	100	1071	100	3043	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 54

TABLE 47

IF THERE WAS A CHARGE IN THE WINTER MONTHS, HOW MUCH WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN KITCHEN AND BATHROOM?
ANALYSED BY AGE-GROUPS

WEEKLY AMOUNTS	UP TO 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 4/6	100	20	128	16	110	14	111	13	449	15
Up to 3/– [1]	227	45	301	37	250	32	223	27	1001	34
Up to 2/– [1]	321	64	478	58	386	49	360	43	1545	52
Nothing	48	10	107	13	132	17	133	16	420	14
Don't know	134	27	233	29	268	34	348	41	983	33
TOTAL	503	100	818	100	786	100	841	100	2948	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 55

TABLE 48

IF THERE WAS A CHARGE IN THE WINTER MONTHS, HOW MUCH WOULD YOU BE PREPARED TO PAY FOR CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN THE KITCHEN AND BATHROOM?
ANALYSED BY OLD AND NEW HOUSES

WEEKLY AMOUNTS	NEW HOUSE		OLD HOUSE		ALL HOUSES	
	No.	%	No.	%	No.	%
Up to 4/6	125	14	337	16	462	15
Up to 3/– [1]	280	31	751	35	1031	34
Up to 2/– [1]	457	51	1130	52	1587	53
Nothing	167	19	263	13	430	14
Don't know	273	30	735	35	1008	33
TOTAL	897	100	2128	100	3025	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 5. 6. 6
A 1. 5. 6. 62

TABLE 49

WOULD YOU STILL LIKE CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN THE KITCHEN AND BATHROOM, IF THERE WERE NO COAL FIREPLACE IN YOUR SITTING ROOM ?
ANALYSED BY DEGREE-DAY REGIONS

ANSWER	REGION I 5000–5500		REGION II 4500–5000		REGION III 4500–4000		REGION IV UNDER 4000		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	32	24	378	43	637	55	509	40	1556	45
No	101	76	511	57	526	45	761	60	1899	55
TOTAL	133	100	889	100	1163	100	1270	100	3455	100

Refer to Text
A 1. 5. 6. 64

TABLE 50

WOULD YOU STILL LIKE CENTRAL HEATING IN THE SITTING ROOM AND CONSTANT HOT WATER IN THE KITCHEN AND BATHROOM, IF THERE WERE NO COAL FIREPLACE IN YOUR SITTING ROOM?
ANALYSED BY AGE-GROUPS

ANSWER	UP TO 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	277	49	428	46	396	43	406	43	1507	45
No	282	51	499	54	527	57	535	57	1843	55
TOTAL	559	100	927	100	923	100	941	100	3350	100

Refer to Text
A 1. 5. 7

TABLE 51 A

PARTS OF THE HOUSE IN WHICH CENTRAL HEATING IS PREFERRED

	NO.	%
Upstairs	1902	45
Any room except living room	407	10
Living room only	583	14
Any room except bedrooms	392	9
Working kitchen or scullery only	47	1
Any room except bedrooms and living room	121	3
None at all	496	12
Whole house	272	6

Refer to Text
A 1.5.7

Table 51 B

Reasons why Central Heating is Preferred in Different Parts of the House

Reasons for preference	Upstairs		Any room except living room		Living room only		Any room except bedrooms		Working kitchen or scullery only		Any room except bedrooms and living room		None at all		Whole house	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Prefer fire in living and downstairs rooms	337	18	175	43	—	—	—	—	—	—	4	3	—	—	3	1
Bedrooms cold and damp otherwise	1348	71	180	44	—	—	—	—	—	—	—	—	—	—	2	1
Children less likely to catch cold going to bed	156	8	10	3	—	—	—	—	—	—	—	—	—	—	—	—
Spending more time downstairs	—	—	11	3	510	88	279	71	22	—	5	4	—	—	1	—
Dislike warm bedrooms, unhealthy	—	—	—	—	33	6	54	14	—	—	1	1	—	—	—	—
Better for children downstairs	—	—	—	—	6	1	4	1	—	—	—	—	—	—	—	—
Warm whole house	—	—	1	—	3	—	31	8	—	—	7	6	—	—	—	—
Cold there	1	—	9	2	4	1	1	—	22	—	84	70	—	—	1	—
Prefer fire downstairs, dislike warm bedrooms	1	—	—	—	1	—	—	—	2	—	11	9	—	—	—	—
Don't know	59	3	21	5	26	4	23	6	1	—	9	7	496	100	265	98

Refer to Text
A 1. 5. 7. 1

TABLE 52 A

PARTS OF THE HOUSE IN WHICH CENTRAL HEATING IS PREFERRED
HOUSEHOLDS WITHOUT CHILDREN

	NO.	%
Upstairs	853	43
Any room except living room	194	10
Living room only	266	13
Any room except bedrooms	178	9
Working kitchen or scullery	21	1
Any room except bedrooms and living room	62	3
None at all	288	14
Whole house	137	7

Refer to Text
A 1. 5. 7. 1

TABLE 52 C

PARTS OF THE HOUSE IN WHICH CENTRAL HEATING IS PREFERRED
HOUSEHOLDS WITH CHILDREN

	NO.	%
Upstairs	1149	50
Any room except living room	166	7
Living room only	338	15
Any room except bedrooms	233	10
Working kitchen or scullery	28	1
Any room except bedrooms and living room	57	2
None at all	208	9
Whole house	138	6

TABLE 52 B

REASONS WHY CENTRAL HEATING IS PREFERRED IN DIFFERENT PARTS OF THE HOUSE
HOUSEHOLDS WITHOUT CHILDREN

REASONS FOR PREFERENCE	UPSTAIRS		ANY ROOM EXCEPT LIVING ROOM		LIVING ROOM ONLY		ANY ROOM EXCEPT BEDROOMS		WORKING KITCHEN OR SCULLERY		ANY ROOM EXCEPT BEDROOMS AND LIVING ROOM		NONE AT ALL		WHOLE HOUSE	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Prefer fire in living and downstairs rooms	159	18	87	45	—	—	—	—	1	—	—	—	—	—	3	2
Bedrooms cold and damp otherwise	654	77	88	45	—	—	—	—	—	—	—	—	—	—	1	1
Children less likely to catch cold going to bed [1]	14	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Spend more time downstairs	—	—	5	3	233	88	123	69	9	—	2	—	—	—	—	—
Dislike warm bedrooms, unhealthy	—	—	—	—	19	7	24	14	—	—	1	—	—	—	—	—
Better for children	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Would warm whole house	—	—	1	—	1	—	18	10	—	—	3	—	—	—	—	—
Cold there	—	—	5	3	—	—	—	—	10	—	45	—	—	—	1	1
Prefer fire in living room, dislike warm bedrooms	—	—	—	—	—	—	—	—	1	—	5	—	—	—	—	—
Don't know	26	3	8	4	13	5	13	7	—	—	6	—	288	100	132	96

[1] In these cases young wives were considering future children.

Refer to Text
A 1. 5. 7. 1

Table 52 D

Reasons why Central Heating is Preferred in Different Parts of the House
Households With Children

Reasons for preference	Upstairs		Any room except living room		Living room only		Any room except bedrooms		Working kitchen or scullery		Any room except bedrooms and living room		None at all		Whole house	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Prefer fire in living and downstairs rooms	178	16	59	36	—	—	1	—	—	—	1	—	—	—	—	—
Bedrooms cold and damp otherwise	794	69	74	44	—	—	—	—	—	—	—	—	—	—	1	1
Children less likely to catch cold going to bed	142	12	10	6	—	—	—	—	—	—	—	—	—	—	—	—
Spend more time downstairs	—	—	6	4	298	88	174	75	14	—	3	—	—	—	—	—
Dislike warm bedrooms, unhealthy	—	—	—	—	14	4	30	13	—	—	—	—	—	—	—	—
Better for children	—	—	—	—	6	2	4	2	—	—	—	—	—	—	—	—
Would warm whole house	—	—	—	—	2	1	13	6	—	—	4	—	—	—	—	—
Cold there	1	—	4	2	4	1	1	—	12	—	40	—	—	—	—	—
Prefer fire in living room, dislike warm bedrooms	1	—	—	—	1	—	—	—	1	—	6	—	—	—	—	—
Don't know	33	3	13	8	13	4	10	4	1	—	3	—	208	100	137	99

Refer to Text
A 1. 6. 2
A 1. 6. 2. 1

TABLE 53

METHODS OF HEATING WATER FOR BATHS AND WASHING CLOTHES ANALYSED BY INCOME GROUPS

METHODS	BELOW £160 PER ANNUM				£160–£300 PER ANNUM				ALL INCOMES			
	BATHS		CLOTHES		BATHS		CLOTHES		BATHS		CLOTHES	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Fire Back Boiler, or Range with Piped Supply	484	20	177	7	864	30	295	10	1348	26	472	9
Range with Boiler, without Piped Supply	94	4	32	1	97	3	37	1	191	4	69	1
Copper or Set-Pot (Coal)	418	17	832	35	375	13	802	28	793	15	1634	31
Ideal Boiler or similar	8	—	6	—	60	2	43	2	68	1	49	1
Pans, Kettles, etc., on the Fire, Stove, Range, or Cooker	883	37	488	20	670	24	345	12	1553	30	833	16
Gas Boiler	254	11	601	25	284	10	859	30	538	10	1460	28
Gas Geyser	118	5	58	2	268	10	98	4	386	7	156	3
Electric Immersion Heater	16	1	8	—	57	2	35	1	73	1	43	1
Electric Boiler	20	1	50	2	40	1	111	4	60	1	161	3
Others	101	4	140	6	132	5	224	8	233	5	364	7
TOTAL	2396	100	2392	100	2847	100	2849	100	5243	100	5241	100

Refer to Text
A 1. 6. 3. 1
A 1. 6. 3. 2

TABLE 54

TYPE OF WATER HEATER PREFERRED ANALYSED BY DEGREE-DAY REGIONS

PREFERENCE	REGION I 5000–5500		REGION II 4500–5000		REGION III 4000–4500		REGION IV UNDER 4000		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Fire Back Boiler, Range with Piped Supply	93	65	556	50	596	41	161	11	1406	33
Range with Boiler, without Piped Supply	1	1	6	1	18	1	4	—	29	1
Copper or Set-Pot (Coal)	—	—	5	—	26	2	30	2	61	1
Ideal Boiler or similar type	1	1	11	1	32	2	69	5	113	2
Constant hot water	24	17	348	31	412	28	868	56	1652	39
Gas Boiler	5	4	34	3	61	4	62	4	162	4
Gas Geyser, Storage Heater	2	1	44	4	130	9	206	13	382	9
Electric Immersion Heater	16	11	72	7	140	10	109	7	337	8
Electric Boiler	—	—	37	3	26	2	15	1	78	2
Others	—	—	5	—	9	1	14	1	28	1
TOTAL	142	100	1118	100	1450	100	1538	100	4248	100

Refer to Text
A 1. 6. 4
A 1. 6. 4. 1

TABLE 55

NUMBER OF TIMES WATER WAS HEATED FOR BATHS WEEKLY ANALYSED BY FAMILY SIZE

NUMBER OF TIMES BATH WATER HEATED PER WEEK	1–3 PERSONS		4–7 PERSONS		OVER 7 PERSONS		ALL FAMILIES	
	No.	%	No.	%	No.	%	No.	%
1 or less	761	34	396	18	19	12	1176	26
2	618	28	275	13	18	12	911	20
3	445	20	212	10	12	8	669	15
4	128	6	404	19	6	4	538	12
5	43	2	207	10	5	3	255	6
6	69	3	167	8	12	8	248	5
7	103	5	195	9	19	12	317	7
8	20	1	73	3	22	15	115	3
9	18	1	38	2	12	8	68	2
10	10	—	65	3	8	5	83	2
11	4	—	13	—	4	3	21	—
12 or more	18	1	78	4	15	10	111	2
TOTAL	2237	100	2123	99	152	100	4512	100

Refer to Text
A 1. 6. 4. 2

TABLE 56

NUMBER OF TIMES WATER WAS HEATED FOR BATHS WEEKLY ANALYSED BY HOUSEHOLDS WITH AND WITHOUT SCHOOL CHILDREN

NUMBER OF TIMES BATH WATER HEATED PER WEEK	HOUSES WITH CHILDREN		HOUSES WITHOUT CHILDREN		ALL HOUSES	
	No.	%	No.	%	No.	%
1 or less	460	19	719	34	1179	26
2	359	15	553	26	912	20
3	347	14	325	15	672	15
4	319	13	222	11	541	12
5	191	8	66	3	257	6
6	182	7	72	3	254	6
7	224	9	94	5	318	7
8	92	4	23	1	115	2
9	62	3	6	—	68	1
10	73	3	12	1	85	2
11	20	1	1	—	21	—
12 or more	91	4	24	1	115	3
TOTAL	2420	100	2117	100	4537	100

Refer to Text
A 1. 6. 5. 1

Table 57

Would More Baths be Taken if it was Cheaper or Easier to Heat the Water? Analysed by Degree-Day Regions

Answer		Region I 5000–5500		Region II 4500–5000		Region III 4000–4500		Region IV Under 4000		National	
		No.	%	No.	%	No.	%	No.	%	No.	%
If they cost less	Yes	30	20	711	56	823	48	1321	73	2885	58
	No	119	80	568	44	883	52	480	27	2050	42
	Total	149	100	1279	100	1706	100	1801	100	4935	100
If it were easier to heat water	Yes	55	37	825	65	1081	63	1398	78	3359	68
	No	94	63	445	35	647	37	399	22	1585	32
	Total	149	100	1270	100	1728	100	1797	100	4944	100

Refer to Text
A 1. 6. 6
A 1. 6. 6. 1

Table 58

Would You Like Constant Hot Water Laid on in Your Kitchen and Bathroom (Without Central Heating)? Analysed by Age-Groups

Answer	Age below 30		30–40		40–50		Over 50		All Ages	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	758	93	1131	88	1103	85	1154	81	4146	86
No	55	7	151	12	188	15	275	19	669	14
Total	813	100	1282	100	1291	100	1429	100	4815	100

Refer to Text
A 1. 6. 6. 2

Table 59

Would You Like Constant Hot Water Laid on in Your Kitchen and Bathroom (Without Central Heating)? Analysed by Degree-Day Regions

Answer	Region I 5000–5500		Region II 4500–5000		Region III 4000–4500		Region IV Under 4000		National	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	76	51	1049	82	1495	86	1681	92	4301	86
No	73	49	225	18	234	14	156	8	688	14
Total	149	100	1274	100	1729	100	1837	100	4989	100

Refer to Text
A 1. 6. 6. 4

TABLE 60

WOULD YOU LIKE CONSTANT HOT WATER LAID ON IN YOUR KITCHEN AND BATHROOM (WITHOUT CENTRAL HEATING)? ANALYSED BY NEW AND OLD HOUSES

ANSWER	NEW HOUSE		OLD HOUSE		ALL HOUSES	
	No.	%	No.	%	No.	%
Yes	1192	75	2862	91	4054	86
No	393	25	297	9	690	14
TOTAL	1585	100	3159	100	4744	100

Refer to Text
A 1. 6. 7
A 1. 6. 7. 1

TABLE 61

HOW MUCH WOULD YOU BE PREPARED TO PAY PER WEEK FOR CONSTANT HOT WATER ONLY? ANALYSED BY AGE-GROUPS

ANSWER	BELOW 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 2/6	202	28	242	28	272	25	223	20	939	25
Up to 2/–[1]	337	47	382	44	454	41	384	34	1557	41
Up to 1/6[1]	479	67	580	67	701	63	590	52	2350	62
Nothing	37	5	63	7	94	9	97	9	291	8
Don't know	194	27	219	25	313	28	436	39	1162	30
TOTAL	710	100	862	100	1108	100	1123	100	3803	100

[1] Includes those willing to pay more.

Refer to Text
A 1. 6. 8. 1
A 1. 6. 8. 2

TABLE 62

DO YOU DO ALL YOUR OWN CLOTHES WASHING? ANALYSED BY DEGREE-DAY REGIONS

ANSWER	REGION I 5000–5500		REGION II 4500–5000		REGION III 4000–4500		REGION IV UNDER 4000		NATIONAL	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	118	78	1102	79	1399	76	1226	67	3845	73
No	34	22	289	21	452	24	615	33	1390	27
TOTAL	152	100	1391	100	1851	100	1841	100	5235	100

Refer to Text
A 1. 6. 8. 3

TABLE 63

DO YOU DO ALL YOUR OWN CLOTHES WASHING?
ANALYSED BY URBAN AND RURAL DISTRICTS

ANSWER	URBAN		RURAL		NATIONAL	
	No.	%	No.	%	No.	%
Yes	3232	73	593	78	3825	73
No	1212	27	171	22	1383	27
TOTAL	4444	100	764	100	5208	100

Refer to Text
A 1. 6. 8. 4

TABLE 64

DO YOU DO ALL YOUR OWN CLOTHES WASHING?
ANALYSED BY AGE-GROUPS

ANSWER	BELOW 30		30–40		40–50		OVER 50		ALL AGES	
	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	587	71	1007	75	1042	77	1073	71	3709	73
No	243	29	328	25	316	23	448	29	1335	27
TOTAL	830	100	1335	100	1358	100	1521	100	5044	100

Refer to Text
A 1. 6. 8. 5

TABLE 65

DO YOU DO ALL YOUR OWN CLOTHES WASHING?
ANALYSED BY INCOME GROUPS

ANSWER	BELOW £160 PER ANNUM		£160–£300 PER ANNUM		ALL INCOMES	
	No.	%	No.	%	No.	%
Yes	1852	78	1977	70	3829	74
No	526	22	860	30	1386	26
TOTAL	2378	100	2837	100	5215	100

Refer to Text
A 1. 6. 9
A 1. 6. 9. 1

Table 66

Information as to Availability of Communal Laundry or Public Wash-House and the Extent of Use Analysed by Income Groups

Is there a communal laundry within ten minutes	Do you use it	Below £160 per annum			Over £160 per annum			All incomes		
		No.	%	%	No.	%	%	No.	%	%
Yes	For all washing regularly	56	24	—	102	30	—	158	28	—
	For all washing occasionally	7	3	—	12	3	—	19	3	—
	For heavy washing regularly	12	5	—	13	4	—	25	4	—
	For heavy washing occasionally	2	1	—	12	3	—	14	3	—
	None	158	67	—	203	60	—	361	62	—
	Total	235	100	13	342	100	16	577	100	14
No		1554		87	1841		84	3395		86
	Total	1789		100	2183		100	3972		100

Refer to Text
A 1. 6. 9. 2

Table 67

The Use Made of Communal Laundries Analysed by Family Size

Is there a communal laundry within ten minutes	Do you use it	1–3 persons			4–7 persons			7 persons and over			All families		
		No.	%	%	No.	%	%	No.	%	%	No.	%	%
Yes	All regularly	54	18	—	95	36	—	9	—	—	158	27	—
	All occasionally	11	4	—	8	3	—	1	—	—	20	4	—
	Heavy regularly	12	4	—	12	5	—	1	—	—	25	4	—
	Heavy occasionally	2	1	—	11	4	—	1	—	—	14	3	—
	None	215	73	—	137	52	—	8	—	—	360	62	—
	Total	294	100	15	263	100	14	20	100	14	577	100	15
No		1680		85	1586		86	118		86	3384		85
	Total	1974		100	1849		100	138		100	3961		100

Refer to Text
A 1. 6. 10
A 1. 6. 10. 1

Table 68

What Washing Do You Send to the Laundry? Analysed by Income Groups

Type of washing sent to laundry	Income below £160 per annum		Income £160–£300 per annum		All incomes	
	No.	%	No.	%	No.	%
All washing	52	11	97	11	149	11
Heavy washing only	436	89	765	89	1201	89
Total	488	100	862	100	1350	100

Refer to Text
A 1. 6. 12

Table 69

What Does Laundry Cost Each Week Summer and Winter? Analysed by Income Groups

Cost per week	Winter						Summer					
	Income below £160 per annum		Income £160–£300 per annum		All incomes		Income below £160 per annum		Income £160–£300 per annum		All incomes	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Up to 1/–	116	23	131	15	247	18	117	26	125	16	242	20
1/1–2/–	185	37	257	29	442	32	164	37	245	31	409	33
2/1–3/–	128	25	250	28	378	27	101	23	223	28	324	26
3/1–4/–	42	8	122	14	164	12	33	8	112	14	145	12
4/1–5/–	22	4	75	9	97	7	15	3	52	6	67	5
5/1–6/–	7	2	24	3	31	—	7	2	24	3	31	2
6/1–7/–	2	—	7	1	9	1	—	—	7	1	7	1
7/1–8/–	4	1	8	1	12	1	5	1	7	1	12	1
8/1–9/–	—	—	3	—	3	—	—	—	2	—	2	—
Total	506	100	877	100	1383	100	442	100	797	100	1239	100

PART III. MISCELLANEOUS

THE QUESTIONNAIRE

HEATING OF DWELLINGS INQUIRY

WARTIME SOCIAL SURVEY — NEW SERIES NO. 13

Town...........................		*Income* (Total Household)	
Urban........................	1	Below £160 p.a.	1
Rural	2	£160–£300 p.a.	2
Names of Gas and Electric Companies		Rent and Rates per week (or equivalent payment)	
Gas Meter, Quarterly	1	*Household*	
Prepayment	2	Adults M	
		F	
Electric Meter, Quarterly	1	Lodgers M	
Prepayment	2	F	
		Children of School Age	
Dwelling		Babies under 5	
House........................	1	Total	
Self-contained Flat.............	2		
Scullery		*Housewife*	
Working Kitchen		Working Yes	1
Kitchen-Sitting Room		No	2
Sitting Room		Age Under 30	1
Bedrooms		30–40	2
Bathroom Yes	1	40–50	3
No	2	Over 50	4
New House	1	Occupation of principal wage-earner in family	
Old House	2	....	

1. *Expenditure*

1. How much do you spend on the following :

		£	s.	d.
a. In a winter week, the average of the last four weeks	1. Coal			
	2. Coke, Coalite, etc.			
	3. Paraffin			
	4. Firewood			
	Fire lighters			
b. In a year, housewife's estimate	1. Coal			
	2. Coke, Coalite, etc.			
	3. Paraffin			
	4. Firewood, etc.			
	5. Gas from Company			
	6. Electricity from Company			

2. Do you belong to a Coal Club ? Yes 1; No 2

3. How much do you pay for a cwt. of coal ?.........................

4. How much coal do you buy at a time ?.........................

5. Why do you buy this quantity ?.............................

2. *Cooking*

6. What fuel do you use for cooking?

	Winter	*Summer*
Coal	1	1
Gas	2	2
Electricity	3	3
Oil	4	4

7. a. If you use coal for cooking do you use:

i. an open fire only 1

or a stove which ii. heats another room 2

iii. heats water in a boiler 3

iv. heats water for kitchen sink or bathroom 4

b. If gas, has it a Regulo? YES 1

NO 2

8. Have you cooked with any other kind of stove, range, or oven in the past? ....

....

9. What are your likes and dislikes about the cooking apparatus you have used? ....

....

....

....

10. What type of cooking apparatus would you like best?

....

11. What are your reasons for liking this? ....

....

....

....

12. Have you ever used it? YES 1

NO 2

3. *Heating*

13. At what times and on what days do you heat the following rooms at the present time of year? In what way?

ROOM	TIME OF LIGHTING FIRE [1]		TIME WHEN FIRE IS NO LONGER MADE UP [1]		HOURS	TYPE OF HEATER
	Week-days	Sunday	Week-days	Sunday		
Scullery						
Working Kitchen						
Kitchen-Sitting room						
Sitting room						
Bedrooms 1.						
2.						
3.						

[1] In case of gas and electric fires the times when these are put on and off should be given.

14. a. Have you any likes and dislikes about central heating ?
....
....
....
....

b. Have you had any direct experience of central heating ? YES 1
NO 2

15. Would you like central heating in all your rooms, and constant hot water in your kitchen and bathroom ? YES 1
(No boiler in the house, no stoking, no ashes, etc.) NO 2

16. If there was a charge in the winter months, how much would you be prepared to pay ?

Up to 5*s.*	1
,, 3*s.* 6*d.*	2
,, 2*s.* 6*d.*	3
Nothing	4
Don't know	5

17. Would you still like central heating if there were no coal fireplaces in the house ? YES 1
NO 2

18. Another possible arrangement is to have central heating in the sitting room and constant hot water in the kitchen and bathroom. Would you like this ? YES 1
NO 2

19. If there was a charge in the winter months would you be prepared to pay ?

Up to 4*s.* 6*d.*	1
,, 3*s.*	2
,, 2*s.*	3
Nothing	4
Don't know	5

20. Would you still like this arrangement if there was no coal fireplace in your sitting room ? YES 1
NO 2

21. If it was possible to have part of your house centrally heated which part would you choose ?..
....

22. Why..
....
....

4. *Water Heating, Baths, and Laundry*

23. How do you heat water for : a. Baths..........................
b. Washing clothes ....

24. What other kind of water heating have you had in the past ?
....

25. What are your likes and dislikes about these ?
....
....
....
....

26. What kind of hot-water supply would you like best ?

....

27. How many times a week do you use hot water for baths ?

....

28. Would more baths be taken if a. they cost less ? Yes 1
No 2
b. if it was easier to heat the water Yes 1
No 2

29. Would you like constant hot water laid on in your kitchen and bathroom (without central heating) ? Yes 1
No 2

30. How much would you be prepared to pay for this ?
Up to 2*s.* 6*d.* 1
,, 2*s.* 2
,, 1*s.* 6*d.* 3
Nothing 4
Don't know 5

31. Do you do all your own washing ? Yes 1
No 2

32. Is there a communal laundry or public wash-house within 10 minutes' walk ? Yes 1
No 2

33. Do you use it for : a. Regularly for all washing 1
b. Occasionally for all washing 2
c. Regularly for heavy clothes, sheets, overalls, etc. 3
d. Occasionally for heavy clothes, sheets, etc. 4
e. None 5

34. What clothes do you send to the laundry :
a. All your washing 1
b. Heavy clothes sheets, overalls, etc. 2
c. None 3

35. Do you use a. Finished service 1
b. Bagwash 2

36. What does it cost each week
a. In winter
b. In summer

Comments :

Field Worker..........................

Date..................................

Address:..

Name ....

TOWNS AND THE SAMPLE IN DEGREE-DAY AND GEOGRAPHICAL REGIONS

Geographical Regions

URBAN

Scotland
- Edinburgh
- Glasgow
- Kilmarnock
- Paisley
- Lanark
- Coatbridge
- Hamilton
- Dundee
- Perth
- Aberdeen

North
- Newcastle
- Gateshead
- Sunderland
- Stockton
- Darlington
- Middlesbrough
- York
- Leeds
- Wakefield
- Sheffield
- Doncaster
- Bradford
- Huddersfield
- Dewsbury
- Carlisle
- Barrow-in-Furness
- Preston
- Burnley
- Bury
- Warrington
- Wigan
- Southport
- Manchester
- Salford
- Oldham
- Liverpool
- Birkenhead
- Crewe
- Stockport

Midlands
- Grimsby
- Lincoln
- Peterborough
- Mansfield
- Derby
- Nottingham
- Leicester
- Northampton
- Birmingham
- Walsall
- Coventry
- Wolverhampton
- Stoke-on-Trent
- Shrewsbury
- Worcester
- Norwich
- King's Lynn
- Ipswich
- Cambridge

London and South
- Watford
- Romford
- Chelmsford
- Southend
- Deptford
- Hammersmith
- Islington
- St. Pancras
- Brixton
- Lewisham
- Wandsworth
- Ealing
- Tottenham
- Ilford
- Chatham
- Dartford
- Maidstone
- Brighton
- Guildford
- Weybridge
- Oxford
- Reading
- Southampton
- Portsmouth
- Basingstoke
- Winchester
- Aylesbury

South-West and Wales
- Taunton
- Bristol
- Wells
- Gloucester
- Swindon
- Chippenham
- Truro
- Penzance
- Torquay
- Barnstaple
- Exeter
- Newport
- Ebbw Vale
- Cardiff
- Merthyr Tydfil
- Caerphilly
- Swansea
- Aberystwith
- Brecon

RURAL

Scotland
- Dumfries
- Perth
- Aberdeen
- Ayr

North
- Ormskirk
- Carlisle
- York
- Lincoln

London and South
- Lewes
- Maidstone
- Winchester

South-West and Wales
- Calne
- Dorchester
- Bridgwater
- Exeter
- Truro

FIG. 3. GEOGRAPHICAL REGIONS

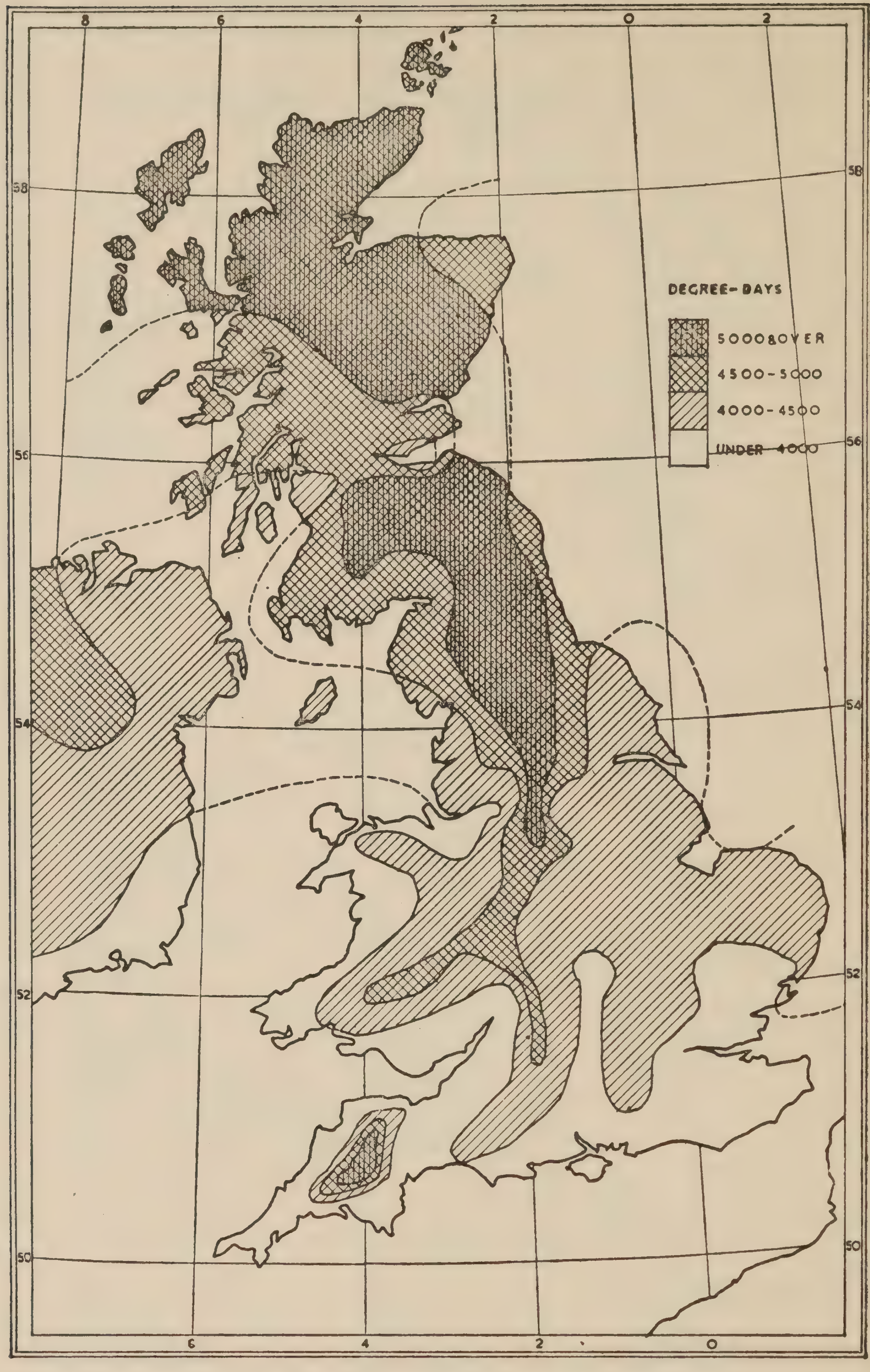

FIG. 4. DEGREE-DAY REGIONS
(After Dufton)

Regions by Degree-Days

Region I
5000–5500 *Degree-days*
Lanark
Bradford
Huddersfield
Dewsbury
Darlington

Region II
4500–5000 *Degree-days*
Perth
Edinburgh
Aberdeen
Ayr
Dumfries
Carlisle
Stoke
Wolverhampton
Worcester
Brecon
Swindon
Calne
Mansfield
Derby
Sheffield
Wakefield
Leeds
York
Stockton
Middlesbrough
Sunderland
Newcastle
Gateshead
Burnley
Dundee

Region III
4000–4500 *Degree-days*
Doncaster
Southport
Grimsby
Lincoln
Barrow-in-Furness
Nottingham
Exeter
Birmingham
Walsall
Coventry
Leicester
Peterborough
King's Lynn
Cambridge
Guildford
Weybridge
Aylesbury
Watford
Merthyr Tydfil
Ebbw Vale
Caerphilly
Swansea
Shrewsbury
Crewe
Stockport
Manchester
Salford
Hamilton
Coatbridge
Kilmarnock
Bury
Wigan
Ormskirk
Liverpool
Preston
Warrington
Glasgow
Paisley
Norwich
Chippenham

Region IV
Up to 4000 *Degree-days*
London
Chelmsford
Romford
Ipswich
Southend
Maidstone
Dartford
Lewes
Brighton
Southampton
Portsmouth
Winchester
Basingstoke
Reading
Oxford
Northampton
Dorchester
Gloucester
Bristol
Wells
Taunton
Bridgwater
Torquay
Barnstaple
Truro
Penzance
Newport
Cardiff
Aberystwith
Birkenhead
Chatham

RURAL

North
Aberdeen
Perth
Ayr
Dumfries
Carlisle
Ormskirk
York
Lincoln

South
Maidstone
Lewes
Winchester
Dorchester
Bridgwater
Truro
Calne
Exeter

APPENDIX 2

THE APPROXIMATE DETERMINATION OF EQUIVALENT TEMPERATURE

PORTABLE APPARATUS

A 2. 1. Portable apparatus has been devised suitable for use when electricity supply is not available. The apparatus comprises a black-painted cylindrical thermometer, 12 in. high and 4 in. in diameter, together with a kata-thermometer which enables a correction to be made for air movement and for the relatively small size of the cylinder.

The whole equipment, including a folding tripod 27 in. high and a flask containing hot water for heating the kata-thermometer, packs into the cylinder, which is fitted with a carrying handle.

The equivalent temperature is computed as $aT-bH+c$, where T is the temperature of the cylinder and H the kata cooling-power, and a, b and c are constants. Experiments show that the equivalent temperature is approximately $0{\cdot}85\ T-H+14{\cdot}7$, but the constants in this expression are regarded as provisional.

KATA-THERMOMETER

A 2. 2. The kata-thermometer is an alcohol-in-glass thermometer with a cylindrical bulb about 4 cm. long and 2 cm. in diameter. Marks on the stem correspond to temperatures of 100° F. and 95° F. In use, the bulb is warmed to a temperature well above 100° F. by means of hot water, and the bulb is carefully dried. The time taken for the thermometer to cool from 100° to 95° is determined by means of a stop-watch. If this time is t secs., and the kata-factor (usually inscribed on the thermometer) is F, the cooling power is $H=\frac{F}{t}$.

The air velocity if required can be found from the relation

$$\frac{H}{\theta}=0{\cdot}1086+0{\cdot}01584\sqrt{v}$$

where $\theta=(97{\cdot}7-\text{air temperature})$ °F.

and $v=$velocity in ft./min.

Care must be taken to shield the thermometer from radiant heat sources.

AIR TEMPERATURE

A 2. 3. The reading of an ordinary thermometer is affected by radiation, and in measuring the air temperature it is essential to surround the bulb with a polished shield open at top and bottom.

It is probable that in rooms where there is no high-temperature radiant heating, such a thermometer will, for practical purposes, afford a sufficiently good indication of the comfort conditions. It cannot be used where high-temperature radiant sources are employed.

APPENDIX 3

HEAT TRANSMITTANCE COEFFICIENTS

Computed heat transmittance coefficients of some typical constructions are given in the Table below. The values quoted are average values for normal exposure, and may be taken as applying to all orientations and degrees of exposures, where these factors are not known. About 10 per cent should be added where the exposure

is severe, and deducted for sheltered sites. Many of the figures given have been taken by permission of the Institution of Heating and Ventilating Engineers from a booklet entitled *The Computation of the Heat Requirements for Buildings*, where more detailed figures giving allowances for exposure and orientation may be found.

CONSTRUCTION		THERMAL TRANSMITTANCE U (B.Th.U. per sq. ft. per hr. per deg. F. difference of air temperature)
WALLS		
BRICKWORK		
Solid, unplastered	4½ in.	0·64
" "	9 "	0·47
" "	13½ "	0·37
Solid, plastered	4½ "	0·57
" "	9 "	0·43
" "	13½ "	0·35
Solid partition walls, plastered both sides	4½ "	0·46
" " " " " "	9 "	0·36
Cavity, plastered (unventilated)	11 "	0·30
" " "	15½ "	0·26
" " (ventilated)	11 "	0·34
" " "	15½ "	0·29
CONCRETE		
Ballast	4 "	0·64
	6 "	0·54
	8 "	0·47
Foamed slag (light mix)	9 "	0·16
Partition walls, foamed slag (light mix)	4 "	0·27
" " clinker	2 "	0·46
LINED CONSTRUCTIONS		
9-in. foamed slag concrete, with ½-in fibreboard		0·14
Do. with 1-in fibreboard		0·12
4-in foamed slag concrete partition wall, with 1-in. fibreboard		0·16
4½-in brick, 2-in. cavity, 3-in. foamed slag concrete		0·24
Do. with ½-in. fibreboard		0·18
Do. with 1-in. fibreboard		0·14
¼-in. asbestos cement sheets, 2-in. cavity, 4-in. foamed slag concrete		0·24
Do. with ½-in. fibreboard		0·18
Do. with 1-in. fibreboard		0·14
9-in. solid brick wall, with ½-in. fibreboard on battens		0·22
Do. with 1-in. fibreboard on battens		0·17
11-in. cavity (unventilated), with ½-in. fibreboard on battens		0·18
Do. with 1-in. fibreboard on battens		0·15
11-in. cavity (unventilated) ; 2-in. wood wool		0·15
¼-in. asbestos cement, 4-in. cavity, 2-in. wood wool, plastered		0·17
SHEET CONSTRUCTIONS		
¼-in. asbestos cement sheet		0·89
Corrugated asbestos cement sheet		1·15
" iron $\frac{1}{16}$ in.		1·20
WOOD		
Exterior, 1 in.		0·50
Interior, 1 in.		0·41
GLASS		
Single glazing		1·00
Double glazing		0·50

CONSTRUCTION	THERMAL TRANSMITTANCE U (B.Th.U. per sq. ft. per hr. per deg. F. difference of air temperature)	
FLOORS ON GROUND [1]		
Ventilated wood floor on joists, bare boards	0·40	
Do. with parquet, linoleum, or rubber	0·35	
Concrete on ground or hardcore	0·20	
Wood-block floor on concrete on ground	0·15	
Tiles on concrete on ground	0·20	
INTERMEDIATE FLOORS	*Heat flow up*	*Heat flow down*
Wood floor on joists, plaster ceiling	0·29	0·22
Do. ½-in. fibreboard ceiling	0·21	0·18
Concrete, 6-in. with 2-in. screed	0·43	0·35
Do. with wood floor	0·30	0·26
FLAT ROOFS		
Asphalt on 6-in. concrete	0·57	
Do. plastered	0·52	
Asphalt on 5-in. concrete, with 2-in. lightweight concrete screed	0·37	
Do. with ½-in. fibreboard on battens	0·20	
Asphalt on 6-in. concrete, 2-in. lightweight concrete screed, plastered	0·34	
Do. with ½-in. fibreboard on battens	0·20	
PITCHED ROOFS		
Corrugated asbestos	1·40	
Do. lined ½-in. fibreboard beneath purlins	0·31	
Corrugated iron	1·50	
Tiles on boards and felt	0·35	
Tiles on battens	1·50	
Do. felted	0·70	
Plaster ceiling with roof space above		
(*a*) tiles and battens	0·56	
(*b*) tiles on boards and felt	0·30	
Tiles on battens, boarded and felted, ½-in. fibreboard ceiling	0·22	
Tiles, battens, boarded and felted, ½-in. fibreboard above joists, plaster ceiling	0·18	
Tiles, battens, felt, boarding above joists, ½-in. fibreboard ceiling	0·18	
Tiles, battens, felt, ½-in. fibreboard and ½-in. eelgrass quilt above joists, plaster ceiling	0·14	

[1] In using these coefficients, the full temperature difference between indoors and outdoors should be taken. Allowance has been made for the fact that the underside temperature will be higher than the outdoor temperature.

APPENDIX 4
ATMOSPHERIC POLLUTION

Much of the information on the occurrence of atmospheric pollution has been abstracted from a memorandum prepared by the Atmospheric Pollution Research Committee, but the Committee state that they themselves have made no attempt to survey the cost of damage caused by atmospheric pollution.

A 4. 1. ILL-EFFECTS OF ATMOSPHERIC POLLUTION

A 4. 1. 1. The ill-effects of atmospheric pollution are many and various. Some are definitely injurious to plant and animal life and to materials, while others are merely a nuisance. The more important of the ill-effects of pollution can be enumerated as follows.

DAMAGE TO CROPS AND LOSS OF YIELD

A 4. 1. 2. Plants are highly susceptible to atmospheric pollution, and the damage arises from the following main factors. A sooty deposit on the leaves blocks up the stomata and reduces the absorption of carbon dioxide. The presence of oxides of sulphur has a direct toxic action on the plant and also increases the acidity of the soil, while the reduction of sunlight and ultra-violet radiation associated with smoky conditions has a generally devitalizing effect. Cohen and Ruston made careful experiments on these effects in Leeds and its surrounding district. They found, for instance, that the rate of absorption of carbon dioxide by leaves at the centre of the town was less than a tenth of that of similar leaves outside it and that their fall was much earlier. The average weight of radishes in the centre was less than half and of lettuces less than a quarter of that of plants from the same stocks grown outside the town. The percentage of sulphur in cabbages grown in the town was double that of cabbages grown outside it, and the weights of the plants grown centrally was less than a seventh of those grown outside. The germination of seeds (*e.g.* Timothy grass) was found to be very greatly affected by the acidity of the rainwater even when other conditions were precisely the same. (Of oats grown outside the town, 98 per cent germinated, whereas only 17 per cent germinated in a central area.) The weight of 100 corns of barley grown from the same seed was found to be 4·85 grams in a smoke-free area and only 1·16 grams in the centre of a polluted area.

In a Canadian research it was found that concentrations of sulphur dioxide ranging from 0·5 to 2·0 parts per million by volume in the air injuriously affected lucerne and barley: in general, concentrations of sulphur dioxide greater than about half part per million volumes of air are injurious to plant life. Cohen and Ruston found a progressive deterioration in similar batches of soil exposed inside and outside the town, which showed a decrease of calcium carbonate, nitrogen, and bacteriological content in the central area compared with the outer areas and an increase in the acidity.

It is not at present possible to assign a monetary value to the loss due to the effects of atmospheric pollution on crops in or near large towns, but the total must be very great, and in areas such as the Midlands, even at considerable distances from industrial towns, the general pollution of the atmosphere no doubt has an injurious effect on crops and all forms of life.

INCREASE OF RICKETS AND RESPIRATORY DISEASES

A 4. 1. 3. The loss of ultra-violet and visible daylight is believed by members of the medical profession who have studied it to give rise to general ill-health, and especially to a high incidence of rickets and tuberculosis in children. While it must be recognized that it is difficult to separate the specific factor of loss of light from the general conditions of poverty which so often accompanies it in industrial towns, it is reasonable to suppose that the effects of pollution are by no means insignificant. Concentrations of sulphur dioxide, such as may occur under certain weather conditions, are believed to affect adversely people with respiratory diseases. Surveys in

Dublin showed a remarkable correlation between deaths from respiratory complaints and the amount of pollution, and it had already been noticed that in London there was a striking correspondence between the pollution and the death rate, both general and from respiratory diseases. Continued exposure to sulphur dioxide in concentrations up to 1 part per million is believed to be unharmful to normally healthy persons, but concentrations greater than 2 or 3 parts per million, such as may occur under certain conditions in towns, may have an adverse effect on health.

LOSS OF ULTRA-VIOLET AND VISIBLE LIGHT

A 4. 1. 4. The loss of ultra-violet and visible daylight reaches quite large proportions. It has been estimated that in Rochdale 42 per cent of the ultra-violet and 38 per cent of the visible light was lost in winter. The annual loss of ultra-violet light amounted to 25 per cent. Annual losses for Sheffield and Salford were 30 per cent and 51 per cent respectively, and the corresponding annual mean concentrations of smoke were estimated at 29 and 47 milligrams per 100 cubic metres in Sheffield and Salford respectively. Thus approximately half the visible and ultra-violet light is cut off by a smoke concentration of $\frac{1}{2}$ mg./cu. m.—approximately that occurring in London. The losses may be as much as 90 per cent under certain weather conditions in winter. Even the general pollution over rural areas is not without effect. The average ultra-violet loss in the country near Leicester is about 5 per cent in winter, but in summer the losses are negligible. The loss of visible daylight is probably of the same order as that of ultra-violet light. In this connection it is of interest to note that the hours of sunshine may be reduced by as much as 50 per cent in highly polluted areas in winter. and about 15 per cent in summer.

LOSS OF VISIBILITY

A 4. 1. 5. The loss of visible daylight imposes a further burden on the community in that artificial lighting has to be used to supplement the natural illumination of buildings. In addition there is the general loss of visibility which seriously affects transport services. Thus during the winter of 1938-9, on days when fog was not present, the visibility at South Farnborough averaged 1·3 times that at Kew, and at Croydon the average was 1·2 times that at Kew. The differences were due to the greater atmospheric pollution at Kew, though this is by no means a heavily polluted neighbourhood. Whether pollution actually increases the frequency of fogs is not certain, but there is little doubt that the pollution adds to the unpleasantness of fogs, and in an extreme case, the combined effect of fog and pollution may be fatal. (The Meuse valley fog of 4-5th December 1930.)

DETERIORATION OF BUILDINGS

A 4. 1. 6. The deterioration of building materials and the corrosion of metals due to atmospheric pollution represents in the aggregate a very considerable sum. There is the actual damage to the fabric of the building and the corrosion of metalwork. Vernon has reported " fogging " on nickel in small amounts of atmospheric sulphur dioxide ; while traces of this gas are active in promoting the rusting of iron and steel. For example, the rate of corrosion of iron at Sheffield is about $2\frac{1}{2}$ to 3 times as great as at Farnborough. The rate of corrosion of non-ferrous metals is about 3 times as great at Birmingham as at Cardington. The practical effect of this is that the cost of paint maintenance of exposed metalwork is far greater in the polluted areas than in a clean atmosphere. It has been stated that many of our ancient monuments which have stood for centuries are now decaying rapidly under the influence of more highly polluted air of the past 100 years. Pollution also to some extent adversely affects the paints which are used for the protection of exterior surfaces. (Evans and Britton, Laurie, and Daniels have reported failures of certain priming paints, wall paintings, and ordinary paints containing basic pigments.) The corrosion of metals and the attack on paints are largely due to the sulphur dioxide, but the damage to building fabrics may go on independently of sulphur dioxide, although the decay is then much accelerated. Sulphur dioxide pollution also leads to the " tendering " of textile fabrics, with consequent reduction of wearing qualities. The tensile strength and tear resistance of leather may be reduced by as much as 90 per cent in 8 to 14 years on exposure to polluted atmospheres ; and paper becomes brittle. Concentrations of sulphur dioxide greater than 2 or 3 parts per million have deleterious effects on materials.

EXTRA CLEANING AND LAUNDRY

A 4. 1. 7. The constant deposit of smoke and grit imposes a heavy additional charge for cleaning, both internally and externally. This affects the individual directly in the extra cost of his laundry and the extra labour involved in cleaning the house and its furnishings. It has been stated that exterior decorating is required by branches of multiple shops every three years in the country as compared with every year in heavily polluted areas.

A 4. 2. ATMOSPHERIC POLLUTION WITHIN THE HOME

A 4. 2. 1. The pollution within the home may be produced (a) directly from the heating appliances used in the house, and (b) from outside sources, *e.g.* domestic and industrial chimneys.

With regard to (a), all solid-fuel appliances cause dust. Smoke (in the case of coal) and sulphur dioxide (with all solid fuel) may arise under adverse conditions. Gas appliances cause no smoke or dust, but in some cases discharge the products of combustion (including water vapour) into the room, although with a good flue, properly terminated, no products should enter. Many gas cookers are fitted without a flue, in which case the products of combustion, which contain small amounts of sulphur dioxide, are discharged into the room. By adequate ventilation, however, the concentration of these products may be so reduced as to render them practically harmless to both health and furnishings. Electrical appliances produce no dust, smoke, or sulphur dioxide pollution within the home.

With regard to (b), pollution entering the house from outside sources is responsible for a considerable amount of the cost and labour involved in cleaning. Some of this is attributable to domestic sources and some to industrial sources, and the proportions are dealt with later.

Damage to internal decorations may be caused by thermal precipitation of dust contained in the room air ; the dirty deposits so formed will depend, among other things, on the appliance used, and are more likely to occur where the major proportion of the heating is in the form of warm air, particularly where such warm air currents come into close contact with walls and ceilings.

A 4. 3. SOURCES OF ATMOSPHERIC POLLUTION

A 4. 3. 1. The nature and sources of atmospheric pollution have already been dealt with in Chapter 5, and the following paragraphs are confined to the degree of pollution attributable to the various fuels under conditions existing in 1938, with an approximate estimate of the cost.

AMOUNT OF ATMOSPHERIC POLLUTION PER TON OF COAL USED IN VARIOUS WAYS

A 4. 3. 2. The relative amounts of pollution attributable to the various types of fuel used in heating buildings, per ton of coal burnt, is estimated as follows :

a. *Bituminous Coal.* About 3 per cent of the weight of bituminous coal used in domestic fires is emitted as smoke and ash : of this about nine-tenths (2·7 per cent) is smoke. The sulphur content of the coal varies, but 1·5 per cent is a reasonable average, and of this amount about 80 per cent is emitted as sulphur dioxide. Thus the burning of 1 ton of coal produces 0·024 ton of sulphur dioxide. This is finally oxidized to sulphur trioxide or sulphuric acid, some of which appears in rainwater in the form of sulphates and some as free acid.
b. *Semi-bituminous Coal.* Very little smoke is produced. The sulphur content of the coal is about 1 per cent, of which 80 per cent is emitted as sulphur dioxide as above : *i.e.* 0·016 ton of sulphur dioxide per ton of fuel. With high combustion temperatures, the proportion of sulphur dioxide emitted will increase.
c. *Anthracite.* No smoke is emitted. The sulphur content and sulphur dioxide emission is the same as in (b) above.

d. *Electricity.* In electricity generating stations, about 0·7 per cent of the coal burnt is emitted as smoke and ash. Only about one-tenth of this is smoke. The sulphur content of the coal is on the average about 1·5 per cent, of which about 90 per cent is given off as sulphur dioxide. The sulphur dioxide produced at the Battersea and Fulham stations is almost entirely eliminated from the flue gases by gas-washing plant. The weight of sulphur dioxide emitted from all stations represents about 2·5 per cent of the total tonnage of coal burnt in generating stations in 1938.

e. *Gas and Coke.* It is more difficult to assess the quantities of smoke and sulphur dioxide produced during the manufacture of gas and coke. The overall smoke production at the works is probably very small. Smoke is emitted from intermittent retorts (both horizontal and vertical) during the charging time ; but the charging time is only a small fraction of the operating period. Continuous retorts are smokeless, and about half the retorts now in use are of this type : their number is increasing. The average smoke production of all gasworks is probably less than 0·05 per cent of the coal carbonized. No smoke is produced by the use of either gas or coke.

About 4·3 million tons of coke are used annually at the gasworks. The sulphur content of the coke is about 1·5 per cent, of which some 90 per cent is emitted as sulphur dioxide, representing about 0·6 per cent of the coal carbonized.

Sulphur dioxide is also liberated when the coke or gas made is burnt. Town gas is treated for the removal of most of its sulphur content, and on the average contains about 20 grains per 100 cu. ft. The total amount of sulphur dioxide produced by gas combustion is thus quite negligible in relation to the general sulphur pollution. As mentioned above, coke contains about 1·5 per cent of sulphur, 80 per cent of which is emitted as sulphur dioxide when the coke is burnt, the weight of sulphur dioxide being about 1·1 per cent of the coal carbonized.

In the aggregate, therefore, about 0·05 per cent of the coal carbonized is lost as smoke, and this may be debited equally between coke and gas. The sulphur dioxide emitted in the manufacture and use of gas amounts to about 0·3 per cent of the coal carbonized, and the corresponding figure for coke is about 1·4 per cent of the coal carbonized.

Table A 4 (1) shows the amount of atmospheric pollution caused per ton of coal burnt in heating buildings in various ways.

TABLE A 4 (1)

APPROXIMATE AMOUNT OF ATMOSPHERIC POLLUTION PER TON OF COAL

METHOD OF HEATING	TONS OF POLLUTION PER TON OF COAL USED		
	Smoke	Ash	Sulphur Dioxide
Bituminous coal	0·027	0·003	0·024
Semi-bituminous coal	small	0·003	0·016
Anthracite	—	<0·003	0·016
Gas	<0·001	—	0·003
Coke	<0·001	0·002	0·014
Electricity	<0·001	0·006	0·025

TOTAL ANNUAL ATMOSPHERIC POLLUTION

A 4. 3. 3. By using the figures in paragraph A 4. 3. 2, and other evidence in regard to railways and industry, an estimate has been made of the total amount of pollution produced annually in this country under the conditions existing in 1938. This is analysed in Table A 4 (2).

TABLE A 4 (2)

TOTAL ATMOSPHERIC POLLUTION PRODUCED ANNUALLY

<table>
<tr><th rowspan="2"></th><th rowspan="2">FUEL USED (MILLION TONS) PER ANNUM</th><th colspan="3">POLLUTION PRODUCED (MILLION TONS) PER ANNUM</th></tr>
<tr><th>Smoke</th><th>Ash</th><th>Sulphur Dioxide</th></tr>
<tr><td>Bituminous coal used by "domestic" consumers</td><td>47·7</td><td>1·29</td><td>0·14</td><td>1·14</td></tr>
<tr><td>Electricity</td><td></td><td></td><td></td><td></td></tr>
<tr><td>at stations</td><td>14·9</td><td>0·01</td><td>0·10</td><td>0·38</td></tr>
<tr><td>in use</td><td>—</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Gas industry</td><td></td><td></td><td></td><td></td></tr>
<tr><td>carbonized at works</td><td>19·1</td><td colspan="2">0·01</td><td>0·12</td></tr>
<tr><td>in use of gas</td><td>314×10^9 cu. ft.</td><td colspan="2">—</td><td>0·01</td></tr>
<tr><td>in use of coke</td><td>8·3</td><td>—</td><td>0·02</td><td>0·21</td></tr>
<tr><td>Anthracite</td><td>2·7</td><td>—</td><td>0·01</td><td>0·04</td></tr>
<tr><td>L.T. Coke</td><td>0·5</td><td>—</td><td>—</td><td>0·01</td></tr>
<tr><td>Coke ovens (carbonized)</td><td>19·1</td><td>small</td><td>small</td><td>0·5 (including use of coke made)</td></tr>
<tr><td>Railways</td><td>12·5</td><td>0·4</td><td>0·1</td><td>0·45</td></tr>
<tr><td>Other industrial uses</td><td>61·3</td><td>0·7</td><td>0·2</td><td>2·20</td></tr>
<tr><td>Total</td><td>177·8</td><td>2·40</td><td>0·57</td><td>5·06</td></tr>
</table>

It may be concluded that the suspended sooty and tarry constituents of atmospheric pollution (smoke) are about equally domestic and industrial in origin, and the ash and gritty deposits are mainly industrial. At present industrial use of coal is responsible for the greater part of the sulphur pollution. But a considerable part of the industrial use is for heating of factories and other commercial buildings.

A 4. 4. DISTRIBUTION OF ATMOSPHERIC POLLUTION

DISTRIBUTION

A 4. 4. 1. The distribution of atmospheric pollution is an important matter. It has already been noted that ash and grit, consisting of relatively large particles, are deposited near their point of origin. Smoke and sulphur dioxide, however, after leaving the chimney spread vertically and horizontally and become so uniformly distributed that four miles downwind a strong source of pollution is difficult to detect by measurements at ground level. Thus in a survey carried out at Leicester for the Atmospheric Pollution Research Committee (D.S.I.R.) a rough analysis was made of the origin of the surface smoke and sulphur dioxide of a district four miles east of Leicester. In westerly winds 30 per cent was found to have come from Leicester, 25 per cent from Birmingham (30-45 miles up-wind) and 45 per cent from elsewhere. Calculations for the concentration of smoke at a point east of Leicester, based on the assumption that it originated from the burning of coal over the whole Midland industrial area, showed close agreement with the concentration observed at that point. The inference is clearly that atmospheric pollution is more than a local or even a regional problem, but a national one. A single community, be it town or city, cannot obtain for itself a truly clean atmosphere, since it is at the mercy of other communities some of which may be quite remote from it. This does not mean that no benefit will come from abatement of local pollution. The high local concentration of pollution in an urban centre before its own smoke becomes disseminated is, of course, far worse than the widely distributed general pollution.

SMOKELESS ZONES

A 4. 4. 2. It has been suggested that the emission of smoke in a part of a town might be prohibited as a means of reducing pollution. The effect of this would be that if the surrounding conditions remain unchanged, such a " smokeless zone " would not reap the whole benefit of reduction in emission of pollution, because pollution would still reach it from neighbouring districts.

INTENSITY OF ATMOSPHERIC POLLUTION

A 4. 4. 3. The following data, for the average rate of deposit in tons per square mile per month during the three-year period April 1936 to March 1939, are taken from a memorandum prepared for the Study Group by the Atmospheric Pollution Research Committee.

TABLE A 4 (3)

RATE OF DEPOSIT OF POLLUTION

(tons per square mile per month)

POSITION		TAR	OTHER CARBONACEOUS MATTER	TOTAL SOLIDS
London				
Golden Lane	½ m. from Guildhall	0·59	3·14	22·8
Kew Observatory	7 m. W.	0·20	2·01	10·2
Godalming	33 m. S.W.	0·10	1·04	6·9
Garston	20 m. N.W.	0·08	2·39	11·4
Rothamsted	22 m. N.W.	—	1·15	6·9
Glasgow				
Glasgow Cross	Centre	0·36	5·95	30·1
Queen's Park	2 m. S.	0·15	2·32	16·2
Glasahoil	35 m. N.	0·05	0·61	11·1
Stoke-on-Trent				
Tunstall	Centre	0·23	3·93	19·1
Loggerheads	12 m. S.W.	0·05	0·61	4·9

As a result of observations at 14 places in London, pollution is estimated to be deposited at an average rate of 20 tons per square mile per month. In the winter of 1938-39 the average concentration of sulphur dioxide in eight London districts was 0·13 parts per million by volume. The mean concentration at Westminster Bridge in the same winter was 0·19 parts per million. Applying data collected in the Leicester survey, this may represent a maximum concentration at one instant of time as high as 2 parts per million

A 4. 5. COST OF ATMOSPHERIC POLLUTION

A 4. 5. 1. To come now to the assessment of the cost of atmospheric pollution to the community at large, it will be seen that it is very difficult to establish an all-embracing and reliable figure which takes all the effects into account. Some of the effects of pollution are directly assessable in terms of money ; others could in the long run be so assessed, though only indirectly ; but some are quite incapable of monetary assessment. In spite of these difficulties, various estimates of the cost of pollution have been made at different times, and all agree that in this country pollution results in the needless expenditure of many millions of pounds annually.

A re-examination of the cost capable of direct monetary assessment has been made for the purposes of this Report.

A 4. 5. 2. The cost of pollution in Pittsburgh was estimated in 1913 to be £2,160,000, *i.e.* about 87*s.* per head per annum. A comparison of the total deposits in Pittsburgh, Manchester, and London leads to the conclusion that the cost in Manchester would be about 30*s.* per head per annum, and in London about 24*s.*

A survey made in 1919 by the Air Pollution Advisory Board of the Manchester Corporation gave the total cost as £750,000 (or 20*s*. per head per annum). The Pittsburgh figure included loss of daylight and the consequent greater use of artificial lighting, loss of merchandise and trade, and a variety of other factors.

An analysis of the estimated costs in Pittsburgh shows :

Cleaning and redecoration	15 per cent of total
Laundry	25 ,, ,,
Renewal of curtains	4 ,, ,,
Corrosion of metalwork	10 ,, ,,

Some corresponding figures for Manchester were obtained by the Advisory Board by comparison of the costs of laundry in Manchester and in Harrogate :

Laundry	£240,000 (32 per cent)	6*s*. 4*d*. per head per annum
Washing and renewal of curtains	£38,000 (5 per cent)	1*s*. ,, ,,
Total	£750,000	20*s*. ,, ,,

It will be seen that the proportions are in substantial agreement with the Pittsburgh figures. The estimated cost for cleaning and redecoration in Manchester (taken at 15 per cent given by the Pittsburgh survey) is £110,000 or 3*s*. per head per annum. The extra cost of laundry is roughly confirmed by figures given by the Ministry of Labour in 1940: industrial working class households spent 6*d*. per week more on laundry, soap, and cleaning materials than did agricultural households.

The damage to buildings is very difficult to assess, but in evidence submitted at the Fulham power station inquiry (1930) Sir Frank Baines estimated that the cost to the nation totalled £2·4 million per annum.

A further item which may be debited to atmospheric pollution is the loss of unburnt smoke and gases arising from the incomplete combustion of coal. The unburnt gases, apart from the carbon monoxide, are largely innocuous, and are not normally classed as pollutants. The carbon monoxide concentration does not rise to a dangerous level. The unburnt smoke, however, does pollute the air, and the cost of this smoke as fuel may be legitimately included in the cost of pollution.

With regard to the loss of vegetation due to pollution, it is impossible to arrive at a definite value, but one isolated case is of interest. It was estimated that whereas under rural conditions the cost of replacement of dead plants in the Manchester parks would amount to only £80 a year, the actual cost amounted to £1500 under existing conditions.

Summarizing, the monetary value of the more tangible effects of atmospheric pollution is estimated to be approximately as follows :

	COST PER ANNUM TO NATION £ MILLION
Cleaning and redecoration of houses and shops	5·6
Laundry and washing and renewal of curtains	13·8
Damage to buildings	2·4
Unburnt smoke from domestic fires (1·29 million tons at 52*s*. a ton)	3·3
Unburnt smoke from other sources (1·11 million tons at 20*s*. a ton)	1·1
	26·2

This figure represents the very minimum cost, and includes only about half the factors considered in the Pittsburgh survey. There is reason to believe that the final cost in this country would be not less than twice the above figure, when it is remembered that increased corrosion of metals, loss of daylight, damage to crops and to health of man and beast, and dislocation of transport services have all been omitted. Account ought also to be taken of the extra labour involved in cleaning and laundry. (It was estimated that the extra washing in Manchester required on the average an hour per week per family longer than in Harrogate.)

A 4. 5. 3. For the purposes of the following Tables a total cost of £45 million per annum, or roughly 20*s*. per head, has been assumed. It is difficult to apportion

the damage due to smoke and sulphur dioxide respectively, though it would be safe to assume that most of the tangible effects, detailed above, are due to smoke, and most of the intangible effects are due to sulphur dioxide. The costs have therefore been allocated as follows :

Cost of damage due to smoke	£21 million
Cost of damage due to sulphur dioxide	£20 million
Loss due to unburnt smoke	£4 million
Total	£45 million

Approximately half this total is attributable to railway and industrial purposes and half to domestic heating.

COST OF ATMOSPHERIC POLLUTION DUE TO VARIOUS METHODS OF HEATING

A 4. 5. 4. The cost of pollution produced by the various fuels may be evaluated from Table A 4 (2), and expressed as so much per unit of fuel used. In evaluating the cost of pollution, then the value, as fuel, of the unburnt smoke must be included ; but in evaluating the total cost of heating, only the cost of the damage due to smoke and sulphur dioxide should be added to the heating costs, since the latter already includes the value as fuel of the unburnt smoke.

An estimate of the cost of pollution when fuel is used in different ways for heating is shown in Table A 4 (4). The comparison is of value in bringing to light the great importance of the open coal fire in the problem of pollution, and shows the urgent necessity for reducing the amount of smoke it produces.

TABLE A 4 (4)

COST OF POLLUTION FROM VARIOUS FUELS

		DOMESTIC COAL FIRE	ANTHRACITE	GAS	COKE	ELECTRICITY
Fuel used or manufactured (millions per annum)		47·7 tons	2·7 tons	1600 therms	8·3 tons	20,000 kWh.
Cost of smoke	£ millions	11·3	—	0·05	0·05	0·1
	per unit	4/9 per ton	—	¾d. per 100 therms	1½d. per ton	1d. per 1000 kWh.
Cost of sulphur dioxide	£ millions	4·50	0·16	0·28	1·07	1·50
	per unit	1/11 per ton	1/2 per ton	4¼d. per 100 therms	2/7 per ton	1/6 per 1000 kWh.
Total to be added to heating costs	£ millions	15·80	0·16	0·33	1·12	1·60
	per unit	6/8 per ton	1/2 per ton	5d. per 100 therms	2/8½ per ton	1/7 per 1000 kWh.
Cost of unburnt smoke	£ millions	3·3	—	—	—	—
	per unit	1/5 per ton	—	—	—	—
Total cost of pollution		8/1 per ton	1/2 per ton	5d. per 100 therms	2/8½ per ton	1/7 per 1000 kWh.

THE COST DUE TO THE OPEN DOMESTIC FIRE

A 4. 5. 5. It will be seen that the domestic use of coal is responsible for a pollution cost of £15·8 millions representing 7*s*. per head per annum out of the total of 10*s*. per head per annum for all domestic fuels. Suppose, however, all consumption of bituminous coal in domestic premises were stopped, the gasworks and electricity generating stations increasing their output to cope with the resulting greater demand. In the process, the latter would emit a great deal more impurities into the air than at present. The domestic use of coke moreover would still involve the discharge of sulphur dioxide, so that the saving in the cost of pollution would be much less than might be anticipated ; and on the basis of the costs considered in this Appendix, it would be about 5*s*. per head per annum, still leaving 5*s*. per head per annum due to domestic purposes or 15*s*. per head in total.

THE COST PAYABLE BY THE HOUSEHOLDER

A 4. 5. 6. If only the pollution cost paid by the householder be considered, it reduces itself to the extra cost of laundry (about 7*s*. 4*d*. per head per annum), house-cleaning, lighting, and doctors' bills, and to the cost of chimney cleaning (estimated at 2*s*. per chimney per annum). Repainting ought perhaps to be included as well, but in the case of domestic property it may not be so closely related to the pollution, being governed to some extent by the traditional " life " to be expected from re-decoration. It must again be emphasized that this is a very conservative estimate.

It may thus be that the financial argument for the reduction of smoke and sulphur dioxide would not weigh greatly with the average householder, although the aggregate cost to the nation has been shown to be quite large. The other benefits arising from a reduction of pollution are difficult to over-emphasize. These have already been discussed in paragraph A 4. 1. 1 *et seq.*

A 4. 6. THE MITIGATION OF ATMOSPHERIC POLLUTION

A 4. 6. 1. The following paragraphs summarize the steps which have so far been taken in mitigation of pollution by each fuel industry, and clearly indicate that these industries are fully alive to the problem of pollution and aware of the necessity for its reduction.

SOLID FUELS

A 4. 6. 2. The three main steps towards the reduction of atmospheric pollution in the solid-fuel industry are the use of fuels which are smokeless either naturally, such as anthracite and dry-steam coals, or by virtue of carbonization ; the better cleaning and preparation of coal for the market, thereby reducing the impurities, particularly in the form of iron pyrites, which give rise to sulphur fumes ; and the more complete combustion of bituminous coal.

There has been a steady increase over a long period of years in the consumption of smokeless solid fuel, both natural and carbonized. The coal industry has greatly increased the practice of washing coal before despatch from the colliery, and now approximately 60 per cent of the coal produced is so cleaned. A further 10 per cent is cleaned by hand-picking on belts, most of the coal so cleaned going to the domestic market. No very great progress towards the smokeless combustion of bituminous coal in domestic appliances was made before the war, although the increased thermal efficiency, with reduced total consumption, of course effected a corresponding reduction in the smoke emitted to the atmosphere. The most important technical advance prior to the war was the demonstration that bituminous coals, both caking and non-caking, can be burned smokelessly, provided the method of firing and the draught conditions are appropriate. Prior to the war, these principles of smokeless combustion had been applied almost exclusively to the large industrial firing equipment, but it had already been shown by experimental work that a considerable reduction in smoke can be obtained in domestic appliances by appropriate design and draught control.

GAS

A 4. 6. 3. Atmospheric pollution from gasworks has been reduced by the increased adoption of continuous carbonization, by modern methods of coke-quenching, and by reduction in the quantity of fuel used for heating retort settings. With regard to the sulphur in the gas supplied, the gas industry is under statutory obligation to remove completely the hydrogen sulphide which forms 95 per cent of the sulphur compounds present. The recovery of benzole results in the removal of 50 per cent or more of the organic sulphur compounds remaining. Processes have been developed with the object of reducing the total sulphur content of town gas to an insignificant figure, but such processes are not yet in general use. Coke is dealt with under solid fuels above.

ELECTRICITY

A 4. 6. 4. Soot pollution from generating stations has been overcome to a great extent by the improved design of boilers resulting in the more complete combustion of coal. These improvements have chiefly centred around the introduction of secondary air, heightening of combustion chambers and the compartmenting of stokers where the latter are of the chain-grate type. Dust and grit emission is now largely prevented by electrostatic precipitation and grit arrestors which have been installed in practically all generating stations of public electricity supply undertakings and which are now made compulsory when new generating plant is installed. Not less than 90 per cent of the dust is removed by the process, and in some cases even higher guarantees have been given. Gas-washing plant for the removal of sulphur has so far been installed at two large power stations, which generate one-tenth of the total electricity requirements of the country (owing to the higher efficiency of these stations, the coal burnt is only about 6 per cent of the total). In addition to the above stations, gas-washing plant has been installed at three other stations for the partial removal of the sulphur in the flue gases. In the case of the two large power stations mentioned above, the gas-washing plant removes from 93 to 97 per cent of the whole of the sulphur from the flue gases, and at the same time entirely removes soot, dust, and grit. The local ground concentration of all forms of pollution from electricity generating stations has been reduced by the use of high chimneys : the minimum height recommended by the Committee appointed by the Electricity Commissioners in 1932 was 2½ times the height of nearby buildings.

APPENDIX 5

BRITISH STANDARDS RELATING TO HEATING INSTALLATIONS IN BUILDINGS

SUBJECT	B.S. NO.	TITLE	SCOPE
General	617–1935	Identification of Pipes, Conduits, Ducts, and Cables in Buildings.	Standard colours and labels for different services.
	874–1939	Definition of Heat Insulating Terms and Methods of Determining Thermal Conductivity and Solar Reflectivity.	As title.
	476–1932	Fire Resistance, Incombustibility, and Non-Inflammability of Building Materials and Structures.	Definitions and methods of test.
	526–1933	Definitions of Gross and Net Calorific Value.	
	1016–1942	Methods for the Analysis and Testing of Coal and Coke.	Sampling, chemical analysis, physical tests and calorific value.
	1043–1942	Code of Practice for the Provision of Engineering and Utility Services in Buildings.	
Appliances	717–1936	" Combustion Testing " of Domestic Gas Appliances.	Methods of test to ensure combustion does not lead to production of harmful gases. Refers to cooking appliances, water heaters, and gas fires.
	948–1941	Cooking Tests for Gas Ovens	Aim is to provide tests which would reveal defects in cooking performance. Efficiency in terms of quantity of fuel used not included but a minimum warming-up time is given.
	744–1937	Testing Electric Boiling Plates for Domestic Purposes—Methods of.	Object is to make possible comparisons of performance of different makes. No minimum standard laid down. No attempt to define relative importance of the various properties, speed, thermal efficiency, life, and insulation.
	758–1937	Domestic Hot-Water Supply Boilers Burning Solid Fuel. Part 1, Specification.	Rating, fuel capacity, heating surface, fire grates, and dampers. For three types (*a*) anthracite or alternative smokeless fuels, (*b*) coke, (*c*) either anthracite or coke. Ranges, fire-back, and hopper-fed boilers not included. Recommendations for installation are included.
		Part 2. Method of Testing.	To determine whether particular designs comply with rating and design requirements of Part 1.

SUBJECT	B.S. NO.	TITLE	SCOPE
Appliances	758–1943	Part 3. Materials, Construction, and Scantlings.	
	779–1938	Cast Iron Boilers for Central Heating and Hot-Water Supply.	For steam boilers of over 5 sq. ft. heating surface operating at pressures below 15 lb. per sq. in. *Also* hot water central heating boilers of over 5 sq. ft. heating surface operating at pressures below 52 lb. per sq. in. *Also* hot water supply boilers of over 5 sq. ft. heating surface operating at pressures below 52 lb. per sq. in. Deals with quality of material, strength of boiler or boiler sections, safety valves, etc. Does not cover methods of testing.
	780–1938	Riveted Steel Boilers for Hot-Water Central Heating and Hot-Water Supply.	For boilers operating at pressures below 65 lb. per sq. in. Deals with quality of material, construction and workmanship, relief valves, etc., on lines of 779 above. Boilers all to be tested at works to twice working pressure.
	855–1939	Welded Steel Boilers for Hot-Water Central Heating and Hot-Water Supply.	Similar to 780 above.
	854–1939	Welded Steel Boilers for Steam Central Heating.	For boilers operating at pressures below 30 lb. per sq. in. Similar to 780 above.
	799–1938	Fully Automatic Oil Burning Equipment for Central Heating and Hot-Water Supply—Code for.	
	438–1941	Cooker Control Unit.	Case, circuit, fuses, etc., for control units for domestic electric cookers.
	699–1944	Copper Cylinders for Domestic Purposes.	Materials, manufacture, and thickness.
	843–1939	Thermostatically Controlled Thermal Storage Electric Water Heaters with Copper Containers from 1½ to 100 gal. capacity.	Materials, design, dimensions, loading and testing.
	853–1939	Calorifiers.	Steel, cast iron, and copper calorifiers for central heating and hot-water supply. Applies to all sizes of steam heated calorifiers, and to water calorifiers exceeding 50 gal.
	922–1940	Domestic Electric Refrigerators.	Construction, wiring and performance.
	1115–1943	Routine Testing of Domestic Gas Cooking Ovens.	General tests, combustion test, cooking test and performance.

SUBJECT	B.S. NO.	TITLE	SCOPE
Gas Tubing and Connectors	570–1934	Plug and Socket Gas Connectors for Portable Appliances.	Restricted to apparatus of consumption not exceeding 40 cu. ft. per hr. Covers $\frac{3}{16}$-in. dia. tubing. Deals with dimensions and quality.
	669–1934	Flexible Metallic Tubing and Connectors for Portable Gas Appliances.	Covers $\frac{3}{16}$-, $\frac{1}{4}$-, and $\frac{5}{16}$-in. tubing. No reference to consumption per hour. Deals with dimensions and quality.
Flue Pipes, etc.	567–1934	Asbestos Cement Flue Pipes and Fittings for Gas-Fired Appliances.	Dimensions and quality including curing time. Hydraulic test for soundness. Lengths 1 ft. to 6 ft. Diameters 2 in. to 12 in.
	766–1938	Baffles or Draught Divertors on Gas Appliances including Recommendations for Flue Terminals.	Baffle must be suitable to particular appliance. Position of terminals of prime importance. Resistance to corrosion is dealt with although performance of the baffles is the main object.
	835–1939	Asbestos Cement Flue Pipes and Fittings (Heavy Quality) for Domestic Heating Stoves.	Dimensions of pipes and fittings and quality. Hydraulic test for soundness. Lengths 1 ft. to 6 ft. Diameters 3 in. to 12 in. First 3 ft. of pipe not to be in asbestos cement. Methods of connecting asbestos cement to metal.
	715–1936	Sheet Metal Cylindrical Flue Pipes, Fittings, and Accessories for Gas-Fired Appliances.	Dimensions of pipes and fittings and quality of various finishes. Lengths 6 in., 12 in., 18 in., 24 in. Diameters 2 in. to 6 in.
	41–1908	Cast Iron Flue and Smoke Pipes, Spigot and Socket.	Quality of material and dimensions. Lengths 3 ft. and 6 ft. Diameters 4 in. to 12 in.
	65–1937	Salt Glazed-Ware Pipes, including Taper Pipes, Bends, and Junctions.	Dimensions, tests, and marking.
	416–1936	Cast Iron Spigot and Socket Soil, Waste, Ventilating, and Heavy Rainwater Pipes.	Quality and dimensions.
	1181–1944	Clay Flue Linings and Chimney Pots.	Dimensions and workmanship.
Service Pipes	40–1908	Cast Iron Spigot and Socket Low Pressure Heating Pipes.	Quality of material, dimensions.
	66–1914	Copper Alloy Three-piece Unions for Low and Medium Pressure Copper Tubes.	Quality of material, dimensions.
	99–1922	Copper Alloy Pipe Fittings for Low and Medium Pressure Copper Tubes.	Quality of material, dimensions.

SUBJECT	B.S. NO.	TITLE	SCOPE
Service Pipes	143–1938	Malleable Cast Iron and Cast Copper Alloy Pipe Fittings for Steam, Water, Gas, and Oil.	Dimensions but not composition of materials. 200 lb. per sq. in. for water. 150 lb. per sq. in. for steam, gas, and oil.
	788–1938	Wrought Iron Tubes and Tubulars, Gas (light), Water (medium), Steam (heavy) Qualities.	For bores from $\frac{1}{8}$ in. to 6 in. Manufacture, quality of material, dimensions. Method of packing for transport.
	789–1938	Steel Tubes and Tubulars, Gas (light), Water (medium), Steam (heavy) Qualities.	Similar to 788.
	789A–1940	Steel Tubes and Tubulars, Light and Heavy Weight Qualities. (Revised Weights.)	War Emergency Variation of 789.
	61–1913	Copper Tubes and their Screw Threads.	Dimensions, composition, and tests.
	602–1939	Lead Pipes for other than Chemical Purposes.	Composition and weight for pipes $\frac{3}{8}$ in. to 6 in.
	603–1941	Lead Pipes, B.N.F. Ternary Alloy (No. 2).	
	746–1937	Gas Meter Unions.	Materials and dimensions.
Fans	848–1939	Testing of Fans for General Purposes.	

APPENDIX 6

SOME CHARACTERISTICS OF BRITISH COALS

A 6. 1. The occurrence of the various types of coal is given in the following summary, based on the work of the Coal Survey Laboratories of the Fuel Research Organization of D.S.I.R. The division into different types is arbitrary, but the investigation has produced detailed information on the properties and distribution of the national coal resources.

Scotland. All types of bituminous coals : medium- to high-volatile which are strong-, medium-, and weakly-caking, and some low-volatile coals, including anthracite.

Northumberland and Durham. True caking coals occur in mid-west Durham. From here to the south, south-east, east, and north, there is a fairly regular increase in volatile matter and fall in caking properties through coking coals and gas coals to long-flame steam and house coals. The last-named types occur mainly in the northern part of the Northumberland field.

Cumberland. Mainly strongly-caking coals.

Lancashire and Cheshire. Mainly medium-caking coals, used for gas-making and general manufacturing purposes, and for house coals. A few seams are weakly-caking, while some are very strongly swelling and caking.

North Wales. Weakly- to strongly-caking seams yielding mainly manufacturing and house coals, but gas and coking coals are produced in addition.

NORTH STAFFORDSHIRE. Strongly-, medium-, and weakly-caking seams, yielding coking, gas, manufacturing, and house coals.

YORKSHIRE. Medium- to strongly-caking, but some (particularly "hards") are weakly-caking. Coking coals, gas coals, producer gas coals, locomotive and general manufacturing coals, and house coals.

NOTTINGHAMSHIRE AND DERBYSHIRE. Medium- to weakly-caking coals (broadly from north to south). Locomotive and manufacturing coals, some gas coals and a large output of house coals.

SOUTH DERBYSHIRE, LEICESTERSHIRE, WARWICKSHIRE, CANNOCK CHASE, AND SOUTH STAFFORDSHIRE. All weakly-caking or non-caking coals, used for household and manufacturing purposes.

FOREST OF DEAN. Mainly medium-caking, with some weakly-caking coals. Gas, house, and steam coals.

BRISTOL AND SOMERSET. Mainly strongly-caking coals, with some weakly-caking coals in one locality. Gas, manufacturing, and house coals.

SOUTH WALES. A wide range of types: anthracite, semi-anthracite, dry-steam,[1] caking-steam, coking, and gas coals. Only the high-volatile non-caking house and high-volatile steam coals are absent.

KENT. Gas coals and coking coal, and low-volatile weakly-caking steam coals, finding an increasing market for domestic purposes.

Table A 6 (1) gives some figures for the total production of coal together with figures relating to anthracite, gas coals, and coking coals for 1938.

TABLE A 6 (1)

TOTAL PRODUCTION OF COAL FOR THE YEAR 1938

	MILLION TONS
Total coal raised	227
Total exports	50
Anthracite used at home	2·7
Anthracite exported	3·6
Gas coal used at home	19·1
Gas coal exported	3·8
Coal used in coke ovens	19·1

[1] The term "dry-steam" is applied to non-caking, low-volatile coals.

APPENDIX 7

THE FLUELESS GAS HEATER

A 7. 1. It is essential with any form of flueless heater (whether gas, electric, or hot-water radiator) that some independent and adequate ventilation should be provided. The gas appliance, however, needs special consideration in that products of combustion are discharged into the room. It is impossible to say in general terms when a flueless gas heater [1] may give rise to unpleasant or unhealthy conditions in a room. The question can only be considered in relation to the heat loss from the room, the humidity of the outside air, the number of occupants, the degree of ventilation, and the sulphur content of the gas. It also depends on whether the room is heated continuously or intermittently, and on the absorption of the products of combustion by the walls and furnishings of the room.

A 7. 2. It therefore becomes necessary to consider, as a typical example, a room of 1000 cu. ft. which is heated by a flueless heater burning 10 cu. ft. of gas per hour. This will suffice to maintain the inside temperature at 65° F., when the room is unoccupied, against an outside temperature of 40° F. 4 cu. ft. would maintain the temperature at 50° F., and 6 cu. ft. at 55° F.

1 cu. ft. of gas requires for its complete combustion about 4½ cu. ft. of air, and the products of combustion consist of ½ cu. ft. of carbon dioxide and 1 cu. ft. of water vapour. In addition, small quantities of sulphur oxides are formed in proportion to the amount of sulphur present in the gas, and very small amounts of nitrogen oxides and carbon monoxide may also be formed.

The Advisory Committee of the Royal College of Physicians stated that the threshold of perception of combined sulphur dioxide and trioxide is about 0·0001 per cent, or 1 p.p.m., and the safety limit for prolonged exposure to SO_2 is about 0·001 per cent. They add that there is no evidence that harm can result from prolonged exposure to small concentrations of sulphur oxides corresponding to the threshold of smell. The concentrations attained in continuous use and in intermittent use over periods greater than 1 hour with ventilation amounting to 1½ air-changes per hour are shown in the Table below.

TABLE A 7 (1)

SULPHUR DIOXIDE CONCENTRATION

In Rooms with Continuous Use of Flueless Appliances

SULPHUR CONTENT OF GAS (gr./100 cu. ft.)	SULPHUR DIOXIDE CONCENTRATION (%) Gas rate		
	4 cu. ft./hr.	6 cu. ft./hr.	10 cu. ft./hr.
10	0·00004	0·00006	0·00010
20	0·00008	0·00012	0·00020
30	0·00012	0·00018	0·00030

It is seen that unless the sulphur content of the gas is low, only small quantities of gas may be burned in this room under the stated conditions of ventilation unless

[1] A flueless gas heater is one in which all products of combustion are discharged into the room.

the presence of sulphur oxides is to be perceptible by smell. It should be noted that this calculation makes no allowance for the absorption of the sulphur oxides by the walls and furnishings of the room, and it is found that in fact from 50 to 75 per cent of the gases are so absorbed. This absorption is deleterious to fabrics and books, which suffer decay on prolonged exposure to low concentrations of sulphur dioxide.[1]

A 7. 3. In general, the threshold limit of 0·0001 per cent of sulphur oxides (calculated as SO_2) will not be exceeded if the ventilation is at least that given by the equation :

$$nV = 15\ Sx \qquad (1)$$

where nV is the volume of ventilating air in cu. ft./hr.,

S the sulphur content of the gas in gr./100 cu. ft.

and x the gas rate, in cu. ft. per hour.

In this expression, again, no allowance has been made for absorption by the walls and furnishings.

In any case, of course, the volume of ventilating air should not be less than 600 cu. ft./hr. per person, *i.e.*

$$nV = 600\ N \qquad (2)$$

where N is the number of occupants.

Thus, in an occupied room, the ventilation should be at least that given by (1) or (2), whichever is the greater. In such cases it is unlikely that the humidity will be much greater than 75 per cent, particularly if allowance is made for absorption by the walls and condensation on the glass.

A 7. 4. Sulphur dioxide has no apparent physiological effects in the concentrations normally encountered in outside air in metropolitan areas (up to about 1 p.p.m.). Other evidence suggests that concentrations of 10 p.p.m. (0·001 per cent) can be withstood for a considerable period of time, and much higher concentrations, breathed occasionally, have no permanent ill-effects. (See Appendix 4.)

Sulphur trioxide is dangerous only in concentrations greater than about 5 p.p.m. although discomfort may result at 1 p.p.m. The concentration of the combined oxides of sulphur is, however, to be less than 1 p.p.m. ; and as SO_3 forms only about 20 per cent of these oxides, no physiological effects will result from exposure to this constituent of the products of combustion of gas.

For the remaining products of combustion the concentrations which would be dangerous to health on prolonged exposure are shown in Table A 7 (2).

TABLE A 7 (2)

	OBJECTIONABLE	DANGEROUS
Nitrogen peroxide	40 p.p.m.	100 p.p.m.
Carbon monoxide	0·02%	0·1%

Even in the case considered above, in which 10 cu. ft. of gas is burnt each hour in a 1000-cu. ft. room with ventilation amounting to 1½ air changes, the concentration of none of these gases reaches the dangerous limit, or is even objectionable.

A 7. 5. The above analysis suggests that the question of the use of flueless gas appliances would be much more dependent on the extent to which damage to furnishings etc. can be tolerated, than on the effect of the products of combustion on health. It is likely, however, that in the majority of cases the smell of the products will be the deciding factor in the use of a flueless heater

[1] Concentrations of up to 1 p.p.m. may be encountered in the air of large towns, which may thus be more damaging in these same respects. (See Appendix 4.)

A 7. 6. It has been estimated that if the gas rate is 1 cu. ft. per hr. per 100 cu. ft. of room volume, the temperature rise will be approximately 25° F. On this basis, the ventilation necessary to keep the sulphur oxide concentration below the perceptible limit in a 1500 cu. ft. room when 10-gr. gas (*i.e.* gas containing 10 gr. of sulphur per 100 cu. ft.) is used is about 2250 cu. ft. per hr., or 1½ air changes ; but if 30-gr. gas is used, as much as 4½ air changes would be necessary. Absorption of SO_2 by furnishings etc. will allow of a reduction (down to half or less) in the quantities of ventilating air necessary to prevent the smell from becoming noticeable.

A 7. 6. 1. To maintain a 10° temperature difference between inside and outside, about 6 cu. ft. of gas would be burned each hour in this room. The ventilation requirement on the basis of the sulphur oxides is then about 2700 cu. ft./hr., or about 2 air changes, when 30-gr. gas is used. If a supplementary form of heating were employed beneath a flue, the ventilation would be assured, and comfort conditions attained.

In a room with a flue, but without the supplementary form of heating, it is doubtful whether the ventilation would be sufficient to keep the sulphur concentration within the permissible limit if the sole source of warmth were the flueless heater burning 6 cu. ft. of 30-gr. gas per hr. ; (however, the greater concentration of sulphur oxides may not be objectionable from the health point of view because the room would not be occupied all the time). No such difficulty would be encountered if the sulphur content of the gas were to be reduced to 10 grains per 100 cu. ft.

A 7. 7. It appears, therefore, that with gas having a sulphur content of 20 to 30 gr. per 100 cu. ft., the flueless heater can be used without danger to health and without causing an objectionable smell, for warming a hall or landing, and for providing a certain amount of air-heating as background warming in a living room, provided a ventilation rate of at least 1½ air-changes per hour can be assured during its use, but it would be undesirable to recommend its use as the sole means of warming a living room. (It may be mentioned that before the war over 500,000 flueless heaters were in use in homes, offices, shops, etc. ; and it is understood that there were very few complaints arising from their use.)

A 7. 7. 1. The gas industry has recently set up a committee to inquire into methods of sulphur removal from town gas, and the report has just been issued. The committee were of the opinion that the present sulphur content [1] was too high, as it gives rise to an unpleasant smell or noxious fumes, causes corrosion of the appliances, and is a grave source of trouble in certain industrial processes. Immediate steps to reduce the content to 10 gr. per 100 cu. ft. are urged, using known processes, and future reduction to 3 gr. per 100 cu. ft. is recommended. If the sulphur content of gas is so reduced, it might well be possible to use flueless gas heaters for other purposes than those given above. It would still be necessary to ensure proper ventilation in order to keep the humidity at a reasonable level.

APPENDIX 8. OIL FUELS

A 8. 1. USE OF OIL FUEL

A 8. 1. 1. The use of oil fuel for domestic purposes is not, taking the country as a whole, of comparable importance with the domestic use of other fuels with which this Report is primarily concerned. Nevertheless, oil-burning appliances are widely used in rural areas, and it has therefore been thought desirable to include, as an Appendix, such information as is available to the Committee on the use of oil fuel and of certain gaseous derivations.

ESTIMATE OF CONSUMPTION IN 1937

A 8. 1. 2. Table A 8 (1) prepared by the Petroleum Board gives an estimate of oil consumption in this country for domestic purposes in the year 1937. Present consumption is somewhat less owing to wartime restrictions on oil supplies.

[1] 25 per cent of gas output has sulphur content of less than 15 gr./100 cu. ft.
25 per cent of gas output has sulphur content of 16–20 gr./100 cu. ft.
49 per cent of gas output has sulphur content of 21–30 gr./100 cu. ft.
1 per cent of gas output has sulphur content of greater than 30 gr./100 cu. ft.

Table A 8 (1). Estimate of Consumption of Oil Fuels in 1937

Purpose	Burning Oil [1]		Black Oils		Petrol		Butane	
	Approximate Number of Appliances	Consumption of Fuel Tons	Approximate Number of Appliances	Consumption of Fuel Tons	Approximate Number of Appliances	Consumption of Fuel Tons	Approximate Number of Appliances	Consumption of Fuel Tons
Space Heating only	2,500,000 (many only in occasional use)	198,000	—	—	—	—	—	—
Space and Water Heating	—	—	1,350	18,000	—	—	—	—
Cooking (including ancillary cooking)	1,000,000	125,000	—	—	—	—	—	—
Space and Water Heating and Cooking	—	—	—	—	—	—	No information available	1,600
Lighting—Lamps	Very large	60,000	—	—	—	—		
House Electricity Sets (including water pumping)	20,000	12,000	2,000	5,000	11,000	6,000	—	—
Garage Heaters	150,000	5,000	—	—	—	—	—	—
Total		400,000		23,000		6,000		1,600

[1] It is not possible to separate the burning oil (paraffin) used for household cleaning from that used as fuel. There is also a certain amount of burning oil used in hospitals and other institutions, as well as in hotels, hostels, etc., which is included in the above figures.

In addition to the above, somewhat more than 200,000 tons per annum of gas oil are used for carburetting water gas at gasworks.

A 8. 2. PRE-WAR RETAIL PRICES FOR APPLIANCES AND FUEL

A. 8 2. 1. Before the war, there was a great variety of appliances for the use of burning oil and of butane, covering a wide range of prices.

The following is a general indication of retail prices in 1937:

a. Burning Oil Appliances

	LOWEST PRICE		AVERAGE	HIGH-CLASS PRODUCTS		AVERAGE LIFE (MAKERS' CLAIM)
Lamps	5/- to 12/-		25/-	60/-		Indefinite
Heaters	18/6		30/-	45/- to 60/-		5 years
Garage Heaters	—		35/-	—		10 years
Boilers/Stoves	—		8/-	15/- to 19/-		10 years
	1 burner	*2 burner*	*2 burner*	*3 burner*	*4 burner*	
Cookers (excluding accessories)	20/-	37/6	82/- to 98/-	109/- to 126/-	133/- to 170/-	15 years
Ovens (for use with above)	10/- to 15/-		31/-	37/-		5 years
Wicks	—		6*d.*	1/6		300 hrs.

b. Appliances using Butane

	LOWEST PRICE	AVERAGE	HIGH-CLASS PRODUCTS	AVERAGE LIFE (MAKERS' CLAIM)
Fires	£1 2 6	£2 2 0	£2 15 0	10 years
Gas Rings	0 5 0	0 15 6	—	Indefinite
Cookers	7 5 0	0 10 0	15 0 0	10 years
Water Heaters	4 4 0	14 15 0	5 15 0	10 years

Past experience has shown that actual life is usually less than indicated above, due mainly to neglect on the part of the user, while in normal times the desire to purchase a newer model is, of course, an important consideration.

c. Retail Prices of Oil Products for Domestic Consumption (January 1937)

		REMARKS
Burning Oil—Premier Grade	1/- per gal.	Retail prices not fixed. Includes 1*d.* tax.
Black Oils—Diesel Oil	5¾*d.* per gal.	Delivered Outer Zone. Includes 1*d.* tax.
Light Fuel Oil	5⅝*d.* per gal.	Delivered Outer Zone. Includes 1*d.* tax.
Petrol—Commercial Grade	1/5 per gal.	Bulk delivery, England, Wales, and South Scotland. Includes 9*d.* tax.
Butane	15/- per 28 lb. cylinder	Plus hire charge cylinder, or purchase of cylinder at £1, 5*s.* 0*d.* each.

A 8. 3. SMALL DOMESTIC USES OF OIL FUELS

A 8. 3. 1. Paraffin and similar distillates are the only oils used in small houses, the main applications being for cookers and lamps for room lighting. The appliances embody burners of various types.

TYPES OF BURNERS

A 8. 3. 2. a. *Luminous Flame Type.* In this type of burner the oil is fed from the oil container through the wick to the burner where it burns with a luminous flame. It is used for lighting and to a lesser extent for heating and cooking. It suffers from the disadvantage that it may smoke, and that when used for cooking, or water heating, the flames must not be allowed to impinge on the oven or heating vessel otherwise combustion would be incomplete and soot be produced.

b. *Blue Flame Type.* In this type of burner the oil vapour from the wick or from the burner bowl is mixed with air and subsequently burns with a blue flame. The flames can impinge on the oven or on the vessel which is being heated, and in addition this type of burner is smokeless. It is becoming increasingly used in cooking and heating appliances, and before the war had a greater sale than any other type of burner.

c. *Pressure Type.* These burners work under pressure of 10 to 15 lb./sq. in., and share with the blue flame type the advantage that the flame can come into direct contact with the oven or vessel which is being heated, and that they do not smoke. This type of burner suffers from the disadvantage that lighting up is by no means simple, and that great care has always to be exercised to keep the nipple clean.

APPLIANCES

A 8. 3. 3. Paraffin lamps are of either luminous flame type or a mantle type. Rates of burning of oil lamps in common use vary considerably, and in general the standard of lighting in houses lit by oil is much lower than in houses lit by gas or electricity. An appreciable amount of heat is produced, that from a lamp burning at the rate of one-eighth of a pint an hour being about 2500 B.Th.U. per hour.

Paraffin lamps are commonly used for space heating for short periods when gas and electricity are not available. It is, however, much less common for them to be used to satisfy total heat requirements for long periods. Paraffin space-heating appliances have approximately the same efficiency as the flueless gas heater. The calorific value of paraffin is 1·59 therms per gallon gross and 1·49 therms per gallon net.

Blue flame type of cookers should have approximately the same thermal efficiency as gas and somewhat more than the luminous flame type. However, oil cookers are not usually insulated as efficiently as gas cookers.

The thermal efficiency of paraffin boilers of the luminous flame type is somewhat lower than that of gas rings. It is probable that the efficiencies of the blue flame type and pressure type in which the flames are in direct contact with the vessel approach that of the gas ring.

Comprehensive advice on the economic use of small domestic oil-burning appliances has been given in Domestic Fuel Memo P. 2/1, issued by the Ministry of Fuel and Power. Briefly summarized, the advice given is—keep the appliance clean, keep the paraffin clean and free from water, and keep the wick in order.

It is claimed by the Petroleum Board and by the makers of oil-burning appliances that, in general, dopes are ineffective and in fact on occasions may be harmful.

FUEL CONSUMPTION

A 8. 3. 4. Typical rates of consumption of domestic oil-burning appliances in general use are as follows :

APPLIANCES (ON FULL)	PINTS PER HOUR PER BURNER
Room heater	0·2–0·6
Boilers	0·2–0·6
Cookers	0·2–0·6
Wash Coppers	0·6
Domestic Lighting	0·02–0·25

From 2 to 2½ gallons of paraffin should be sufficient for the whole of the cooking for a family of 3 to 4 people for one week. Various figures have been quoted including the following:

1 gallon will cook 3 meals per day for 3 days for 4 people.
1 „ „ heat a 2-pint kettle 140 times.

1 hot dinner for 4 persons requires 1½ pints.
1 „ „ 6 „ „ 2 „
1 „ „ 8 „ „ 2½ „

ADVANTAGES AND DISADVANTAGES OF PARAFFIN

A 8. 3. 5. Paraffin possesses no definite advantages over gas or electricity. The advantages over coal are a greater rapidity in oven heating, a closer degree of control over rate of burning, and shorter warming-up period for space-heating.

Smell is produced both by the products of combustion and part evaporation of oil which has been spilled or has crept on to the surface of the appliance. Storage capacity has to be provided, and some care has to be taken in filling and cleaning the appliance.

POLLUTION FROM PARAFFIN COMBUSTION

A 8. 3. 6. Practically all small domestic oil-burning appliances are used without flues, and consequently the products of combustion, which include carbon dioxide, water vapour, and oxide of sulphur, are emitted into the room. The risk of carbon monoxide being produced is probably very small. The paraffin normally sold for domestic use has a sulphur content of about 0·05 per cent with a maximum of about 0·1 per cent. For equal heat production the amount of oxides of sulphur given off by paraffin containing 0·05 per cent sulphur is approximately the same as that given off by gas containing 10 grains of sulphur per 100 cu. ft.,[1] and the amount of water vapour produced by the paraffin is about half that produced by the gas.

REGIONAL DISTRIBUTION OF DOMESTIC PARAFFIN USERS

A 8. 3. 7. From the inquiry into the heating of dwellings made by the Wartime Social Survey in March 1942 on 5267 working-class houses both urban and rural (Appendix 1) the following data were obtained:

Space Heating

Sitting rooms: 10 out of 1192 or 0·85 per cent were heated by oil.
Bedrooms: 50 out of 682 or 7·3 per cent were heated by oil.
Cooking: The percentage of houses in which oil was used for cooking were found to be as follows by different regions, expressed as percentages.

	SCOTLAND	N. ENGLAND	MIDLAND	LONDON AND HOME COUNTIES	S. WALES	NATIONAL
Winter	5·7	0·7	0·1	2·8	6·4	2·7
Summer	5·8	0·85	0·25	3·2	8·0	3·1

In the case of coal users using oil for cooking, the following figures were obtained as percentages in urban, rural, and total districts:

	URBAN	RURAL	TOTAL
Winter	0·9	32·5	6·3
Summer	1·4	39·7	8·7

[1] See Appendix 7, paragraph A 7. 2; Appendix 4, paragraph A 4. 1. 6., where reference is made to the effects of sulphur dioxide.

A. 8. 4. GASEOUS DERIVATIVES

PETROL GAS

A 8. 4. 1. Petrol gas is used to a small extent in country houses for both lighting and cooking. It has the advantage over paraffin of being more cleanly.

BOTTLED BUTANE

A 8. 4. 2. Bottled butane is supplied in steel cylinders in liquid form at low pressures, and before the war its use was increasing in country districts. It is used generally for lighting and cooking. It has the advantage over paraffin of greater cleanliness in use and a negligible sulphur content. Efficiencies of the appliances used with it are similar to those with blue flame paraffin burners or with town gas.

This fuel has the national advantage that it is obtained partly from the processing of coal and partly from the cracking of imported oils. It is usually sold in cylinders containing 32 lb. or 14 lb., and costs approximately 2*s.* 10*d.* per therm.

A 8. 5. CENTRAL HEATING BY OIL

TYPES OF OIL USED FOR HEATING BOILERS

A 8. 5. 1. Fuel oils used for heating boilers are confined almost exclusively to five types which are, in order of increasing specific gravity and decreasing cost, diesel oil, domestic fuel oils numbers 1 and 2, 200-secs. oil, and heavy or bunker fuel oil. Diesel oil, while having many advantages for automatic oil burners, is expensive and is used only where existing burners are unable to handle a heavier oil. Burners using heavy fuel oil demand constant attention from an engineer, so that, in spite of its relative cheapness, it is seldom used for heating purposes.

Most burners were originally designed to burn domestic fuel oil numbers 1 and 2, since these oils could be burnt without pre-heating. American burners, many of which were imported into this country, could handle these oils satisfactorily. Leading oil companies standardized the two grades for heating purposes, their specifications being as follows :

	GRADE NO. 1	GRADE NO. 2
Specific gravity at 60° F.	0·88	0·91
Flash point (closed test)	over	150° F.
Viscosity, Redwood No. 1 at 100° F.	40 secs.	not exceeding 70 secs.
Pour test	Fluid at	20° F.
Calorific value B.Th.U. per lb.	19,300	19,200
Gallons per ton	255	246

When fuel oils were taxed, these relatively light oils became expensive, and 200-seconds oil was introduced for heating purposes. As its name implies, this oil has a viscosity of 200 seconds Redwood No. 1, at 100° F., and a higher specific gravity than either of the domestic fuel oils. It needs pre-heating before it can be burnt in heating boiler burners. (See Table A 8 (2).)

TABLE A 8 (2)

SPECIFICATIONS OF 200-SECS. AND BUNKER OILS

	200-SECS.	BUNKER
Specific gravity	0·92	0·95
Flash point (closed test)	over	150° F.
Viscosity, Redwood No. 1 at 100° F.	200	1500
Ash	under 0·05%	under 0·1%
Hard asphalt	4–6%	6–10%
Cold test	below	32° F.
Gallons per ton	244	236

OIL BURNERS

A 8. 5. 2. Before oil can be burnt efficiently and under control it must be broken up into extremely small particles, each of which must be brought into intimate contact with sufficient air for its combustion. Two main methods are used for this breaking-up process—vaporization and atomization. It is only extremely light oil such as paraffin or diesel oil which will vaporize completely and easily. Consequently, this process is used only for paraffin stoves and very small appliances.

Atomization may be effected in various ways, of which five are of importance for heating purposes, namely steam, medium-pressure air, low-pressure air, pressure jet, and rotary burner.

Steam atomization is commonly effected by allowing a stream of oil from a burner to be met by a jet of high-velocity steam. The impact shatters the oil into minute globules.

Medium-pressure air burners employ air at a pressure of 2 lb./sq. in. to 10 lb./sq. in., the most usual pressure being about 5 lb./sq. in. Their action is similar to that of the steam-operated burners except that air replaces steam. Low-pressure air burners operate on the same principle but use an air pressure of 10 to 20 in. water gauge. The air quantity is considerably larger than in the case of medium-pressure burners but the total energy content is about the same. A scent spray is a good example of a low-pressure air atomizer.

Pressure-jet atomization is effected by forcing oil at high pressure through a small orifice, the pressure used in heating boilers being about 100 lb./sq. in. A whirling chamber is fitted behind the orifice plate so that the issuing droplets of oil have a rotary motion giving a wide angle cone-shaped spray.

Rotary burners employ a cup into which oil is fed and which is spun by an electric motor or by air blast. The oil is flung off the edge of the cup, which rotates at about 3000 r.p.m., centrifugal force effecting the actual atomization.

All the methods of atomization described and several others are used for industrial purposes, since each has advantages for particular applications. For the heating of buildings, practice seems to indicate that pressure-jet atomization will eventually displace other methods, which are now in a very small minority.

Pressure-jet burners have the advantage of producing considerably less combustion roar than other types, a very important matter where quietness is necessary. They appear to lend themselves much more readily to automatic ignition by electric spark, and their power consumption is low. These burners are relatively complicated mechanically and demand good workmanship if they are to function in a trouble-free manner. Oil must be well filtered in order to prevent obstruction of the small orifice in the atomizer. The viscosity of the oil must be low.

OIL BURNER CONTROL

A 8. 5. 3. The heat output from a burner may be controlled manually or automatically. In the latter case the control may be floating high-low or on-off. Floating control means graduating the size of the flame to the heat output required. With high/low control the flame is at its maximum for a period and then shuts down to its minimum for a period, the length of the high and low periods being controlled according to the heat output required. On-off control is similar to high-low control except that the burner is extinguished completely at low periods.

Pressure-jet burners are fitted with on-off control. A room thermostat is usually employed, and so long as the room temperature is below the setting of the thermostat the burner gives its full output. When the desired temperature is exceeded the burner is shut off. The thermostat usually has a differential of about 2° F.

A limiting thermostat is fitted to the boiler so that at a set water temperature the burner is extinguished even if the room thermostat calls for heat. A flame-stat prevents explosions due to vaporized oil in the combustion chamber. When the burner is extinguished it cannot start again until the temperature in the chamber is low enough to operate the flame-stat. A safety device prevents accumulations of oil vapour in the boiler at starting up, by shutting down the plant if ignition does not take place within about 20 seconds. A control value allows oil to pass to the atomizer only if its pressure is within the proper limits. Often a time switch is used, so that the temperature maintained in the building is lower during the night than during the day.

OIL STORAGE

A 8. 5. 4. Oil is usually stored in steel tanks preferably external to the building and buried. The minimum capacity used is 2½ tons since bulk deliveries of less than 2 tons are charged at an increased rate. Insurance companies have certain regulations governing the installation of oil storage tanks, and the interested company should be consulted before a tank is fixed.

EFFICIENCY OF OIL BURNERS AND BOILERS

A 8. 5. 5. An efficient atomizer subdivides oil into extremely small particles. This fact, coupled with accurate control of air quantity, full turbulence of oil, air mixtures, and proper placing of refractories, enables high combustion efficiencies to be achieved. Oil contains more hydrogen (about 12 per cent) than coke or most coals, so that an appreciable flue loss due to uncondensed steam is inevitable. However, with 25 per cent excess air and 500° F. flue gas temperature, the stack loss amounts to about 17 per cent. There is comparatively little deposit on the boiler surfaces, so that an average operating efficiency of 80 per cent is readily attained. If 15 per cent internal transmission loss is taken, the appliance efficiency is 68 per cent. Comparing oil with solid fuel, some credit should be given for its flexibility, for the ease with which automatic control may be applied, and for the decrease in labour and attention needed. Capital cost may be higher.

APPLIANCES

A 8. 5. 6. Oil burners of all types and sizes are available in this country, and prior to the war a few boiler burner-units had been imported from America. In these units the boiler is specially designed for oil firing and the whole unit encased in a vitreous enamel jacket without excrescences.

ADVANTAGES AND DISADVANTAGES OF OIL-FIRED CENTRAL HEATING

A 8. 5. 7. Oil has a number of advantages over solid fuel for central heating, among which are convenience and flexibility, ease of automatic control, cleanliness in the building and in the handling of the fuel, saving of space and labour, and generally smokeless combustion.

The disadvantages include higher costs than solid fuel, considering fuel only. Amortization will be similar if automatic stokers are used. Considering labour, running costs may not differ appreciably. There is also the disadvantage that much of the oil used has had to be imported.

SULPHUR CONTENT OF OIL

A 8. 5. 8. The sulphur content of fuel oils varies with the origin of the crude oils from which they are prepared. Average figures are heavy fuel oil 2·1 per cent, light fuel oil 1·4 per cent, and diesel oil 0·9 per cent.

Properly adjusted oil burners applied to boilers produce no smoke (except at starting up), so that the only atmospheric pollution resulting from the combustion will be that due to the sulphur. (See Appendix 4.)

GLOSSARY OF TERMS

BRITISH THERMAL UNIT (B.Th.U.) is the amount of heat required to raise the temperature of 1 lb. of water by 1 degree Fahrenheit. 1 kWh.=3415 B.Th.U.

THERM : 100,000 B.Th.U.

CALORIFIC VALUE of a fuel is the amount of heat given out when a specified quantity of the fuel is completely burnt. For coal it is usually expressed as the number of B.Th.U. per lb., and for gas as the number of B.Th.U. per cu. ft. (See *B.S.* 526–1933.)

THERMAL TRANSMITTANCE (sometimes called heat transmittance coefficient, etc.) (U) is the number of B.Th.U. transmitted per hour through a sq. ft. of a material or construction when a difference of temperature of 1 degree Fahrenheit exists between the *air* on the two sides of the material or construction.

THE SURFACE-TO-SURFACE CONDUCTANCE (C) of a material or construction is the number of B.Th.U. transmitted per hour through a sq. ft. of the material or construction when the *surface* temperatures on the opposite sides differ by 1° F.

Degree-day : A unit based upon the temperature difference and time, used in specifying the nominal heating load. For any one day there exist as many degree-days as there are degrees Fahrenheit difference in temperature between the average outside air temperature over a 24-hour period, and a temperature, known as the "base temperature," depending on the temperature to be maintained within the building when the outdoor temperature is below the base temperature. The base temperature is assumed to be 5° F. lower than the maintained temperature. Except where otherwise stated, the annual total of degree-days for all the days of the year is to be assumed. For the normal degree-day in Great Britain, the base temperature is 60° F.

Air change : The rate of air change in a room is the ratio of the actual volume of air entering the room per hour to the volume of the room.

Equivalent temperature of an environment is that temperature of a uniform enclosure in which a black cylinder of height about 22 in. and diameter about 7½ in. would lose heat at the same rate as in the environment under consideration, the surface of the cylinder being maintained at a temperature which is a precise function of the heat loss from the cylinder and which in any uniform enclosure is lower than 100° F. by two-thirds of the difference between 100° F. and the temperature of the enclosure.

Relative humidity : If x is the partial pressure of the water vapour present in moist air, and f is the partial pressure of the water vapour in saturated air at the same temperature, the percentage relative humidity is :

$$r=100\frac{x}{f}$$

Efficiencies of appliances, etc. See Chapter 6.

Background heating : The maintenance of a minimum temperature in a room throughout the 24 hours, this minimum temperature being generally below the temperature required for sedentary occupation.

Topping-up : The provision of extra heat to bring a room to a comfortable temperature during periods of occupation.

BIBLIOGRAPHY

CHAPTER 1

Markham, S. F., M.P., *Climate and the Energy of Nations.*

Transactions of the World Power Conference, 1938, vol. IV.

CHAPTER 2

HEATING

Bedford, *The Warmth Factor in Comfort at Work*, Industrial Health Research Board, Special Report No. 76 (1936).*

Bedford, *Modern Principles of Ventilation and Heating* (Lewis, 1937).*

Bedford, "Ventilation and Heating in relation to Human Comfort," Journal of the Institution of Heating and Ventilating Engineers, 1940, vol. 7, p. 377.

Dufton, *The Equivalent Temperature of a Room and its Measurements*, Building Research Technical Paper, No. 13 (1936).*

Dufton, "The Measurement of Equivalent Temperature," Journal of the Institution of Heating and Ventilating Engineers, August, 1934.*

Dufton, "The Kata-thermometer as Leslie's Anemometer," Journal of the Institution of Heating and Ventilating Engineers, May, 1934.*

Fishenden and Willgress, *The Heating of Rooms*, Fuel Research Technical Paper No. 12.

Fishenden and Dufton, *Heat Transmission*, Building Research Special Report No. 11 (1929).

General Board of Health, *Report by the Commissioners appointed to enquire into the warming and ventilation of dwellings* (1857).

Joint Committee of the Medical Research Council and the Department of Scientific

* Contains a discussion of methods of measuring equivalent temperature.

and Industrial Research, *Report on methods of Measuring the Comfort of an Environment.*

League of Nations Health Organisation, *The Hygiene of Housing, a Report by the Housing Commission* (1937).

Vernon, *Principles of Heating and Ventilation* (Arnold, 1934).*

Building Research Board, Annual Report (1937).*

Yarnold, " Improved Instruments for Measuring the Warmth of Domestic Rooms," Journal of the Institution of Heating and Ventilation Engineers, July, 1936.

VENTILATION

American Society of Heating and Ventilating Engineers, *Heating, Ventilating and Air Conditioning Guide* (1942).

Bourdillon, Lidwell, and Lovelock, British Medical Journal, 1942, No. 1, p. 42.

De Chaumont, *Lectures on State Medicine* (1875).

Wells, Journal of Industrial Hygiene, 1935, vol. 17, p. 253.

Yaglou, Riley and Coggins, " Ventilation Requirements," *Heating, Piping and Air Conditioning*, 1936, vol. 8, p. 65.

WATER REQUIREMENTS

Institution of Heating and Ventilating Engineers, *Guide to Current Practice* (1940).

Report of the Committee on the Construction of Flats for the Working Classes.

COOKING

Masterman, *The Future of Gas Appliance Design*, Institution of Gas Engineers, Communication No. 158/51 (1937). Contains references to tests with all fuels.

CHAPTER 3

Andrew and Barron, *Comfort Heating by Gas*, Institution of Gas Engineers, Communication No. 211/88 (1939).

Billington, " Note on Experiments on the warming of a Room," Journal of the Institution of Heating and Ventilating Engineers, 1940, vol 7, No. 83, p. 477.

Dufton, " Degree-days," Journal of the Institution of Heating and Ventilating Engineers, 1934, vol. 2, No. 14, p. 83.

Dufton, " Heat Requirements of a House," Journal of the Institution of Heating and Ventilating Engineers, 1933, vol. 1, No. 3, p. 156, and No. 4, p. 209.

Dufton, " The Warming of Walls," Journal of the Institution of Heating and Ventilating Engineers, 1934, vol. 3, No. 21, p. 416; Philosophical Magazine 1931, vol. 11, No. 74, p. 1233.

Dufton, " Heat Transmission Coefficients," Journal of the Institution of Heating and Ventilating Engineers, 1940, vol. 7, p. 221.

Dufton and Marley, " The Comparison of Heating Systems," Journal of the Institution of Heating and Ventilating Engineers, 1942, vol. 10, No. 110, p. 17.

Fishenden, *The Coal Fire*, Fuel Research Special Report No. 3 (1920).

Smith, " The Radiant Efficiency of Electric Fires," Journal of the Institution of Electrical Engineers, 1930, vol. 68, p. 1211.

" A Study of the Ventilation of a Warmed Room," Journal of the Institution of Heating and Ventilating Engineers, 1939, vol. 7, p. 79.

Averages of Humidity for the British Isles, M.O. 421, Meteorological Office.

The Book of Normals, Section 1, M.O. 236, Meteorological Office.

The Computation of the Heat Requirements for Buildings, Institution of Heating and Ventilating Engineers (1942).

London Housing, L.C.C. (1937).

CHAPTER 4

Ministry of Fuel and Power, *Thermal Insulation*, Fuel Efficiency Bulletin No. 12 (1943).

Medical Research Council, *Bed-bug Infestation* (1942).

* Contains a discussion of methods of measuring equivalent temperature.

CHAPTER 6

Davidson and Hartley, *Some Results attained with Solid Fuel used in open grates for heating Living Rooms*, Institution of Gas Engineers, Communication No. 200/83 (1938).

Fishenden, *The Coal Fire*, Fuel Research Special Report No. 3 (1920).

Hartley, *The Contribution of the Gas Industry in the Domestic Field to National Fuel Economy*, Institution of Gas Engineers, Communication No. 248 (1942).

Masterman, *The Future of Gas Appliance Design*, Institution of Gas Engineers, Communication No. 158/51 (1937).

Smith, " The Radiant Efficiency of Electric Fires," Journal of the Institution of Electrical Engineers, 1930, vol. 68, p. 1211.

Electricity Commissioners, Annual Reports.

Returns relating to Authorised Gas Undertakings in Great Britain (Board of Trade).

Fishenden, *House Heating* (Witherby, 1925).

CHAPTER 7

Hartley, *The Contribution of the Gas Industry in the Domestic Field of National Fuel Economy*, Institution of Gas Engineers, Communication No. 248 (1942).

" A Study of the Ventilation of a Warmed Room," Journal of the Institution of Heating and Ventilating Engineers, 1939, vol. 7, No. 79.

Dufton, " Domestic Economy," Journal of the Institution of Heating and Ventilating Engineers, 1943, vol. 10, p. 247.

CHAPTER 8

Dufton, " The Ventilation of a Flueless Room," Journal of the Institution of Heating and Ventilating Engineers, 1938, vol. 6, No. 68, p. 428.

Hood, *On Warming and Ventilating Buildings* (Whittaker, 1879).

Warner, " Ventilation of Dwellings," Journal of Hygiene, 1940, vol. 40, No. 2, p. 126.

" A Study of the Ventilation of a Warmed Room," Journal of the Institution of Heating and Ventilating Engineers, 1939, vol. 7, No. 79.

CHAPTER 9

Livett, Official Architect, 1940, vol. 3, No. 1, p. 32.

CHAPTER 10

Industrial Research Council (Eire), *Turf as a Domestic Fuel*, Bulletin No. 2 (1941).

CHAPTER 11

International Housing Association, *Slum Clearance and the Reconditioning of Insanitary Dwellings* (Verlag. Julius Hoffman, 1935).

International Housing Association, *Equipment and Fittings for Small Dwellings* (Verlag. Julius Hoffman).

International Housing Association, *Subsistence Homesteads* (1935).

CHAPTER 12

Dufton, "The Improvement of the Open Fire," Journal of the Royal Institute of British Architects, March, 1942.

Fitzmaurice, *Principles of Modern Building* (H.M.S.O. 1938).

Rietschel-Brabbee, *Heating and Ventilation* (McGraw Hill, 1927).

Rumford, *Of Chimney Fireplaces* (1796).

Vernon, *Principles of Heating and Ventilation* (Arnold, 1934).

Ministry of Fuel and Power, *Heat Insulation* (*Lagging*), Fuel Efficiency Bulletin No. 2.

Ministry of Fuel and Power, *Control of Excess Air*, Fuel Efficiency Bulletin No. 10.

Ministry of Fuel and Power, *Thermostatic Control*, Fuel Efficiency Bulletin No. 11.

BIBLIOGRAPHY

CHAPTER 14

Report on the British Coal Industry, Political and Economic Planning (P.E.P.).

The Gas Industry, P.E.P.

Report on the Supply of Electricity in Great Britain, P.E.P.

APPENDIX 3

The Computation of the Heat Requirements for Buildings, Institution of Heating and Ventilating Engineers (1942).

APPENDIX 4

Shaw and Owens, *The Smoke Problems of Great Cities* (Constable, 1925).

The Black Smoke Tax, Report of the Air Pollution Advisory Board of the Manchester City Council (1919).

No Clean City, National Smoke Abatement Society (1942).

Annual Reports of the Investigation of Atmospheric Pollution (D.S.I.R.).

Cohen and Ruston, *Smoke* (Arnold, 1925).

Baines, Evidence before the Inquiry by the Electricity Commissioners into an Application of the Fulham Borough Council, "The Times," 18th December 1930.

Mellon Institute, Bulletin No. 4 (1913).

Ministry of Labour Gazette, 1940, vol. 48, No. 12, and 1941, vol. 49, Nos. 1 and 2.

"Smokeless Air," Journal of the National Smoke Abatement Society, 1939, vol. 10, No. 40, and 1940, vol. 10, No. 41.

Schaffer, *The Weathering of Natural Building Stones*, Building Research Special Report, No. 18 (1932).

U.S. Bureau of Mines, I.C. 7064 (1939)—a general review of the effects of sulphur pollution.

Daniels, Journal of the Oil and Colour Chemists' Association, 1927, vol. 10, p. 61.

Evans and Britton, Journal of the Society of Chemical Industry, 1930, vol. 49, p. 174T.

Laurie, Journal of the Oil and Colour Chemists' Association, 1927, vol. 10, p. 14.

Research Association of the British Paint, Colour, and Varnish Manufacturers, Technical Paper Nos. 7 and 18.

Vernon, Journal of the Institute of Metals, 1932, vol. 32, p. 21.

Leonard, Verrey and Cowley, Scientific Proceedings of the Royal Dublin Society, 1941, vol 22, No. 41, p 399.

Journal of the National Smoke Abatement Society, 1933, vol. 4, p. 35, and 1937, vol. 8, p. 169.

Report of the Royal Commission on the Distribution of the Industrial Population (H.M.S.O. 1940).

Setterstrom, Industrial and Engineering Chemistry (Industrial Edition) 1940, vol. 32, No. 4.

Analyst, 1933, vol. 58, No. 962, p. 690.

Illuminating Engineer (New York), 1933, vol. 26, p. 188.

Bosanquet and Pearson, Transactions of the Faraday Society, 1936, vol. 32, p. 1249.

Pearson, Nonhebel, and Ulander, "The Removal of Smoke and Acid Constituents from Flue gases by a Non-effluent Water Process," Journal of the Institution of Electrical Engineers, 1935, vol. 77, No. 463, p. 1.

Report on the Measures which have been taken in this country and others to obviate the Emission of Soot, Ash, Grit and Gritty particles from the Chimneys of Electric Power Stations (1932).

Hewson, Pearce, Pollit, and Rees, "The Application to the Battersea Power Station of researches into the elimination of noxious constituents from Flue gases and the treatment of resulting effluents," Chemistry and Industry, 1933, vol. 52, No. 29, p. 593.

Solid Fuel Installations, Post-War Building Studies No. 10 (H.M.S.O. 1944).

APPENDIX 7

Domestic Heating by Gas, considered from the point of view of health and comfort, Royal College of Physicians of London (1936).

Air Vitiation and Gas Appliances, Masterman, Densham, and Dunning, Institution of Gas Engineers, Communication No. 116 (1935).

The Removal of Sulphur from Gas, Institution of Gas Engineers, Communication No. 250 (1942).

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Mr. C. A. Masterman was appointed in February 1943, following the death of Mr. Stephen Lacey; and Dr. E. V. Evans was appointed in July 1943 in place of Sir David Milne-Watson, who resigned owing to pressure of other work. Mr. J. W. J. Townley was appointed in December 1942, and Mr. D. A. Hughes in June 1944. Mr. R. N. Quirk was appointed in place of Sir Harold Hartley, who resigned on account of ill-health. Mr. C. C. Handisyde acted as Secretary until October 1943.

TERMS OF REFERENCE

i. To review existing scientific information and practice in this country and abroad in the heating and ventilation of dwellings.
ii. To make recommendations for practice in post-war building, regard being had both to economy and efficiency for the individual user and to the economical utilization of the national fuel resources.
iii. To make such recommendations for future research as may suggest themselves in considering (i) and (ii).

DISTRICT HEATING SUB-COMMITTEE

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W. M. Selvey, Wh.Sc., M.Inst.C.E., M.I.Mech.E., M.I.E.E., F.Inst.F.
Sir Johnstone Wright, M.Inst.C.E.
H. E. Beckett, *Secretary.*

TERMS OF REFERENCE

To inquire and report on the desirability of developing in this country schemes for the supply of heat for various purposes by means of steam or hot water from a central source.

MINISTRY OF WORKS

POST-WAR BUILDING STUDIES

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4. PLUMBING. By the Plumbing Committee of the Building Research Board of the Department of Scientific and Industrial Research. 2*s.* 6*d.* (2*s.* 11*d.*)
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25. HOUSE CONSTRUCTION. THIRD REPORT. (See Nos. 1 and 23 above.) *Out of print.*
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